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IRON AND STEEL ENGINEER

JUNE • 1940

VOL. XVII NO. VI

Contents

A.I.S.E. Visits Republic Steel Corporation's Canton-Massillon District 20

Welded Blast Furnace Stack—By L. J. Gould, Assistant Chief Engineer of Construction, Bethlehem Steel Company, Bethlehem, Pennsylvania 23

Discussion: Welded Blast Furnace Stack—Presented by W. S. More, Carl Hoffman, Arthur G. McKee, L. F. Coffin, and L. J. Gould 27

Electrical Equipment for the Edgar Thomson Slabbing Mill—By R. H. Wright and B. J. Auburn, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania ... 30

Discussion: Electrical Equipment for the Edgar Thomson Slabbing Mill—Presented by M. H. Morgan, Jr., R. H. Ellis, T. R. Rhea, James Farrington, J. I. Kaspari, and R. H. Wright 36

Modern Lubrication of Existing Equipment—By F. J. Thomas, Lubrication Engineer, Republic Steel Corporation, Cleveland, Ohio 39

Discussion: Modern Lubrication of Existing Equipment—Presented by T. R. Moxley, R. M. Gordon, F. L. Gray, E. S. Glauch, S. A. Newman, and W. H. Mandy 45

Observations on the Heating of Steel from the Metallurgical Standpoint—By E. E. Callinan, Combustion Engineer, and Gilbert Soler, Manager of Research, Timken Roller Bearing Company, Canton, Ohio 49

Discussion: Observations on the Heating of Steel from the Metallurgical Standpoint—Presented by G. M. Coughlin, E. E. Callinan, A. J. Fisher, J. L. Miller, H. V. Flagg, R. I. Gumaer, P. H. Brace, Gilbert Soler, J. R. Behrman, and J. D. Keller .. 54

Modern Maintenance Practice—By T. R. Moxley, General Master Mechanic, Wheeling Steel Corporation, Steubenville, Ohio 58

Discussion: Modern Maintenance Practice—Presented by F. H. Dyke, J. B. Whitlock, H. L. Dawson, T. R. Moxley, E. W. Trexler, J. M. Morris, H. B. Conover, Harry D. Robb, H. H. Shakely, J. S. Green, E. H. Beatty, H. E. Reith, and A. W. Steed 61

New Alloy Plant for Copperweld Steel Company 68

Latest Design and Equipment for the Industry 71

Items of Interest 75

Index to Advertisers 14

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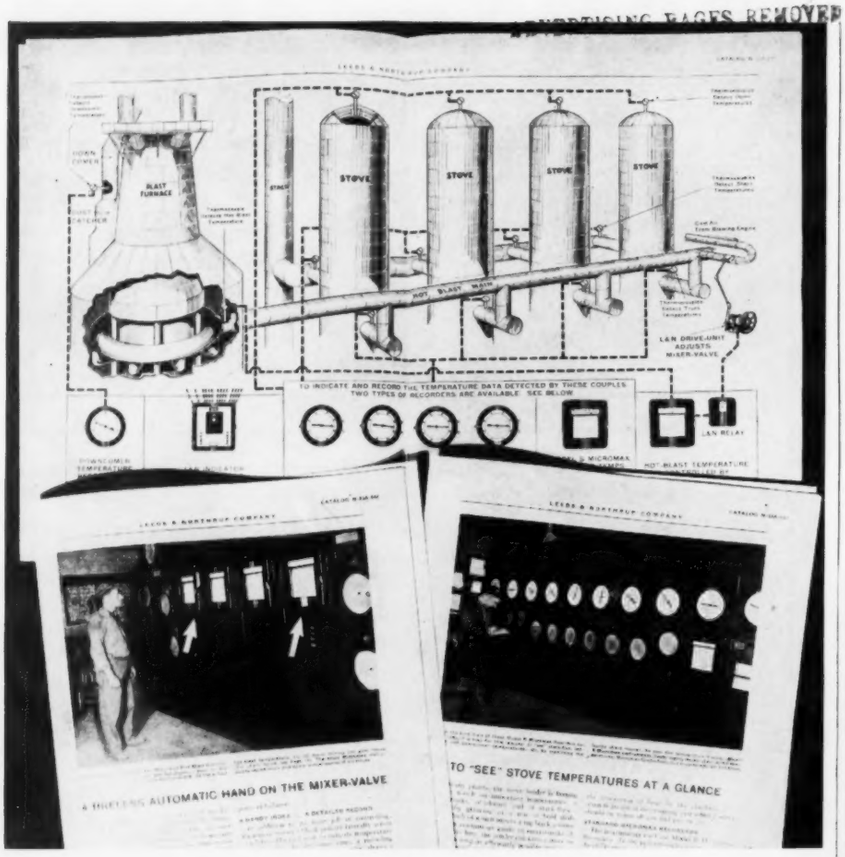
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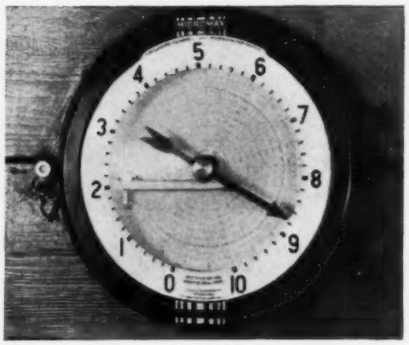

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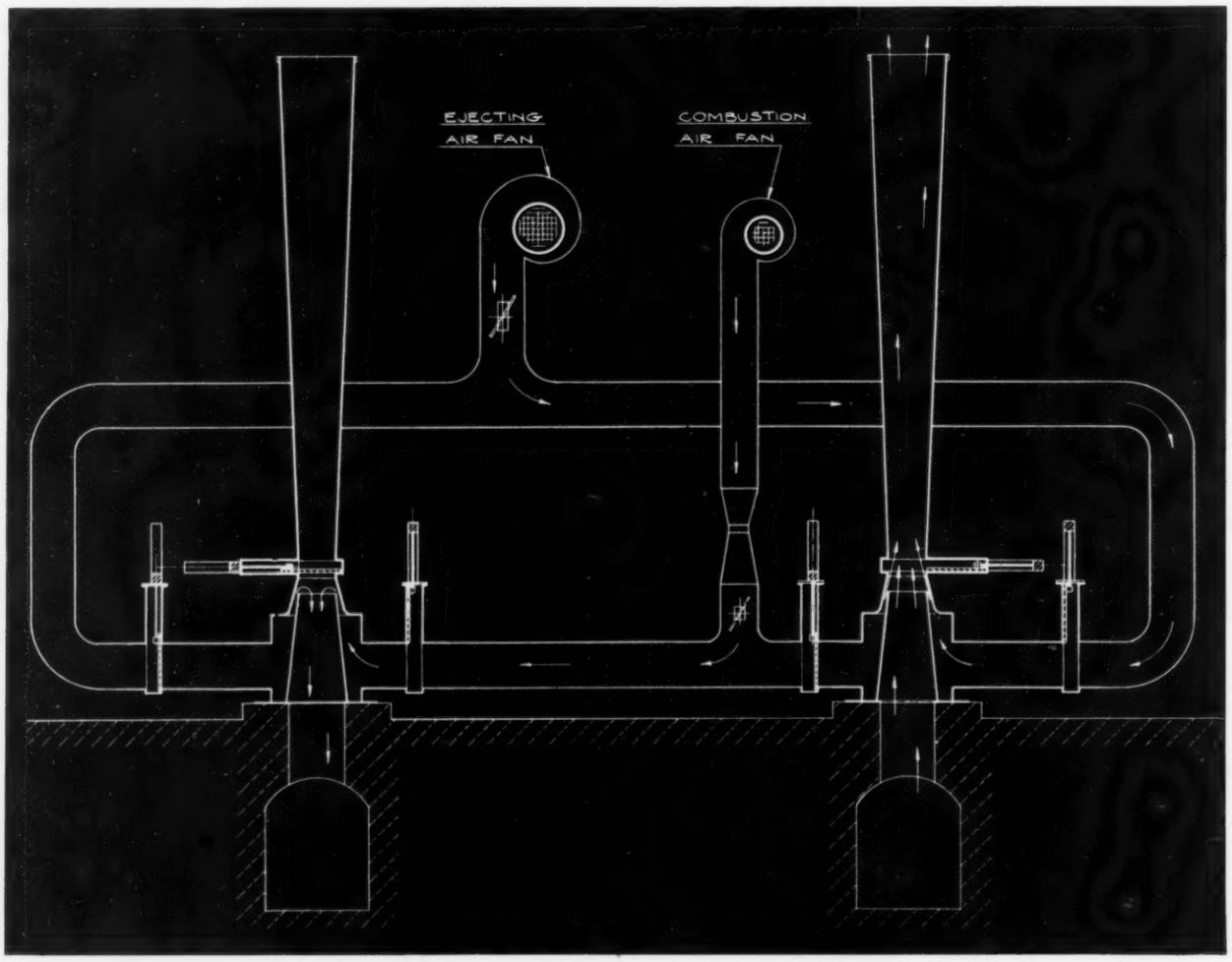

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visits

Canton-Massillon District

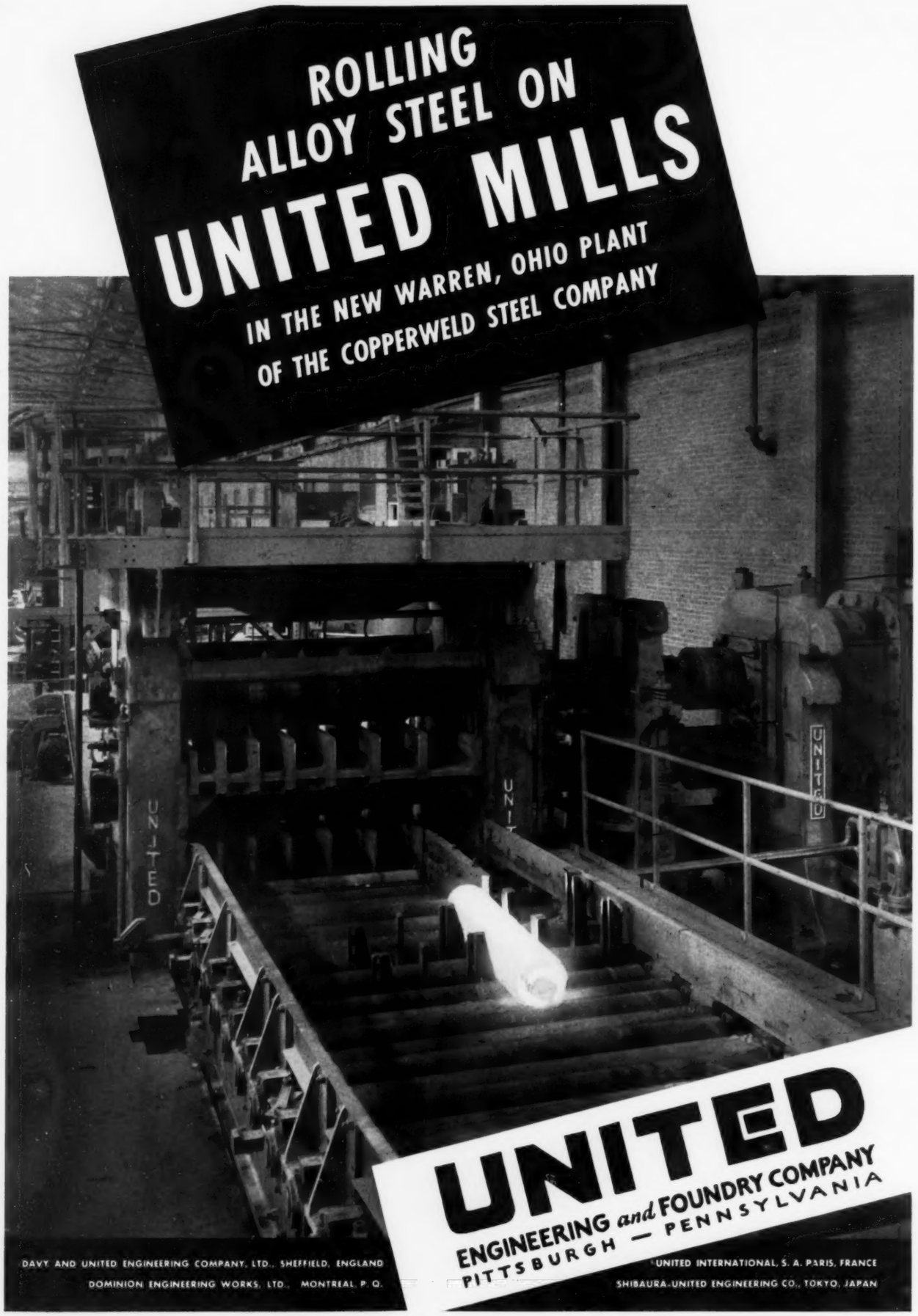
On Tuesday, May 28, the Republic Steel Corporation acted as host to the Association of Iron and Steel Engineers, when an inspection trip to that company's Canton and Massillon plants and a technical session were sponsored by the Cleveland District Section.

Over 300 steel plant engineers and operators registered for this meeting at the Courtland Hotel, Canton, Ohio. W. W. Knight, Jr., and Ross E. Willis *(top, left)* were among the early arrivals. Buses conveyed the party from the hotel to the electric furnace department at Canton and to the stainless steel finishing plant at Massillon. At left, center, is shown Carl W. Meyers, manager of Republic's Central District, as he greeted I. N. Tull, chairman of the Association's Cleveland Section.

The stainless finishing plant includes four new cold strip mills and auxiliary equipment, which, together with previously existing units, gives a total capacity of 1200 tons of stainless steel per month. The plant is under the direct supervision of R. S. Lynch, shown left, below, with H. D. Robb.

Much favorable comment concerning the layout and appearance of the plant was expressed by the visitors, among whom were J. W. Corey and F. C. Watson *(opposite page, top left)*, and C. H. Williams, E. F. Cary, F. D. Johnson, and F. J. Waldschutz *(opposite page, left bottom)*. Local arrangements were handled by J. D. Donovan, who is shown *(opposite page, left center)* with T. F. McNally, E. R. Johnson, T. B. McElray and W. W. Spanagel.

Following an informal dinner, at which Mr. Meyers extended a greeting of welcome, technical papers were presented by H. A. Grove *(bottom, right)*, and by R. E. Kinkead, shown at top, right, with I. N. Tull. H. E. Maser and J. L. Miller *(right, center)* were among the many interested attendants at this meeting.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WELDED

Blast Furnace Stack

By L. J. GOULD

Assistant Chief Engineer of Construction

BETHLEHEM STEEL COMPANY

BETHLEHEM, PENNA.

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pa., September 26-29, 1939

▲ FURNACE "F" at the Maryland Plant of the Bethlehem Steel Company was built in 1920. It had a Nieland top, a 12 ft. 0 in. bell, a 16 ft. 6 in. diameter stockline, a 22 ft. 0 in. diameter bosh and a 17 ft. 0 in. diameter hearth. In 1928 the hearth jacket was increased in size. In 1934 the furnace had a 12 ft. 6 in. bell, a 17 ft. 0 in. diameter stockline, a 23 ft. 0 in. diameter bosh and a 19 ft. 0 in. diameter hearth. These changes were made without any change in the shell of the stack. Figure 1 shows the 1934 lines of the furnace. The operating men felt that these 1934 lines were extremely satisfactory and desired to retain these lines.

Unfortunately, the wall thickness in an area between 10 and 20 ft. below the wearing plates was definitely thin on the original furnace. The few inches reduction of thickness, seems to be the last straw and early failures took place at this point, causing in one case, extremely bad buckles in the shell and necessitating external water-cooling of the shell.

It became evident that we had to increase the wall thickness, thus destroying the optimum lines, or put up with poor life of the stack and the external water-cooling, or we had to increase the shell diameter at the weak points. Studies were therefore directed at some economical method of increasing the shell diameter.

It was at once apparent that if a cylindrical section about 4 ft. 6 in. high were placed on the mantle and a cone developed from this cylinder to the bottom of the hemispherical top, the brick thickness could be increased about 14 in. at the danger zone, and the same interior lines held. The proposed new shell is shown dotted on Figure 1. The cost of the shell itself would not be high, but if it was necessary to remove the whole top rigging and the downcomers, and re-erect them, the expense would be prohibitive and the time excessive. It was determined that a new shell could be erected in such fashion as to make it unnecessary to remove the top. To accomplish this end it was necessary, or at least desirable, to use a great deal of welding.

The serious consequence of failure of a blast furnace shell naturally tends to make operators and engineers a bit over-cautious of using a newer process of jointing. Fortunately we already had considerable experience with the use of welding around a furnace. At first the miscellaneous equipment used in repairs, the platforms, and other brackets, etc., were welded. Later repairs to hot blast main and some new piping were done. The next move was the welding of stove connections. Finally we tackled what we all considered the most important welding job on a furnace—the repair of the hearth jacket. This work also progressed gradually until in 1937 we put a new section 45 ft. 0 in. in length of arc in a 32 ft. 11 in. diameter hearth jacket. This part included the two cinder notches and the tapping hole. It was made of four 2¼ in. thick plates with one horizontal weld and three vertical welds. Two of these vertical welds were, of course, connections to the old plate. The rest of the original riveted jacket was left as it was. This does not constitute an all-welded hearth jacket, but the part that is most likely to cause trouble was welded. Completely welded hearth jackets have been made at the Bethlehem Plant.

As far as we could find out, there were no completely welded stacks in this country, although one was contemplated. Considerable repairs have been made by welding. About the same time the repairs to "F" furnace were under way at Maryland Plant, Bethlehem Plant was making an extensive repair to the stack of "E" furnace. Two complete rings of 8 plates each were installed plate by plate, thus replacing 27 ft. of the stack. These plates were all butt-welded with butt-straps covering the joints. This required about 16 days' time to complete.

In Germany a completely welded blast furnace, the Bochumen Verein No. 2, is in service. A report has been published in Stahl und Eisen, Vol. 58, 1938, but it shows little data on the stack. The hearth jacket has

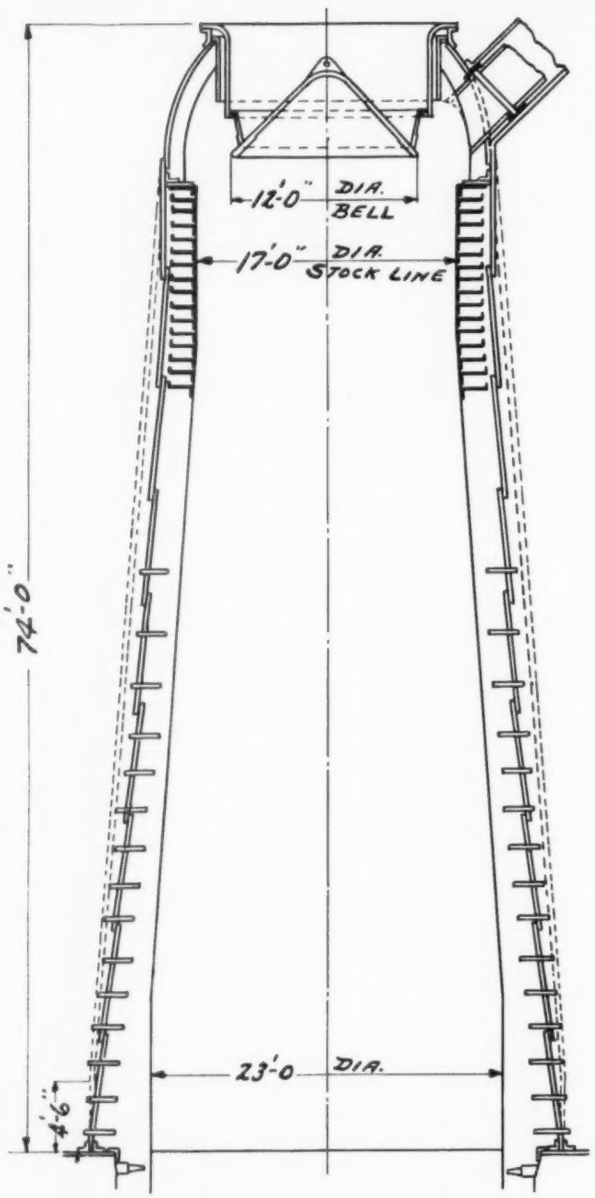


FIGURE 1—Diagram showing lines of "F" furnace, with proposed new shell shown in dotted lines.

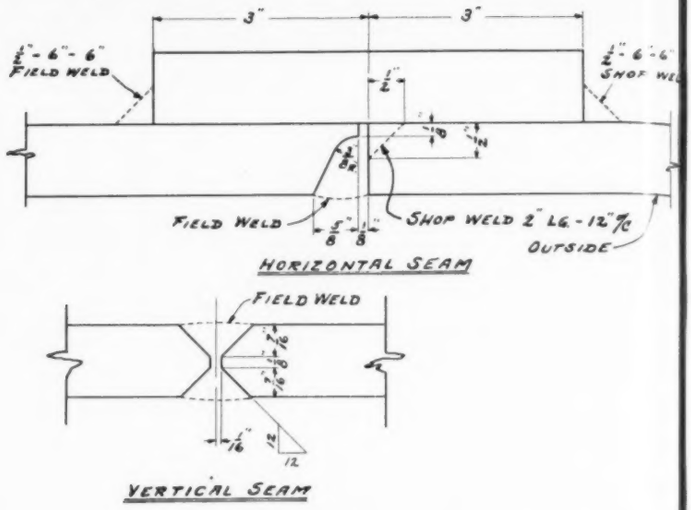


FIGURE 2—Sketch showing details of the welded joints used on the welded furnace stack.

a 1.18 in. thick plate across the whole bottom, then a 13 ft. 0 in. high truncated cone of 2.36 in. plate. On top of the conical section are two cylindrical sections, the lower one 1.77 in. plate, and the upper one 1.18 in. plate. These cylindrical sections are joined to the top of the truncated cone and form continuous plating from the base to the mantle. Incidentally, the bosh and hearth of this furnace are lined with a "tamped carbonaceous mass," 85 per cent ground coke and 15 per cent anhydrous tar.

DESIGN

Referring now to the reconstruction work indicated on Figure 1, it would be very fine to be able to say that we took definitely known loads and applied them to rational formulae which we developed for the design of blast furnace shells. If you examine the very simplest case of buckling of a cylindrical shell, you will see why we decided not to do this—in fact very little information that could be trusted is available. We did roughly check the stresses due to direct load, considering the shell plates as separate plates between cooler holes. We did consider that loads could be applied through the downcomers to the extent of yielding of the downcomers under some condition of settlement of the dust catcher. All these figures were based on the shell without lining. We also considered the bursting pressure due to the stock. It is well for welding enthusiasts to remember that the riveted lap joints and double butt-strapped joints are certain to be stiffer than a butt-weld. The failure of a structure like a blast furnace stack would probably be an "elastic" failure, that is, buckling would take place at a stress below the elastic limit of the material. These factors we calculated as best we could and then proceeded with "Faith, Hope, and an excessive Factor of Safety" to do the detail design, using 1 in. thick plate for the entire shell.

The vertical joints were made standard double "V." It was decided not to use a "U" type because some trimming had to be considered. The horizontal joint is easier to describe than to name. The top of each plate was square and a $\frac{3}{8}$ in. 45 degree notch was cut at intervals on the inner face. A 1 in. x 6 in. butt-strap was welded to this in the notch and at the bottom so that 3 in. projected. The bottom of the top plate had a modified single "U" butt-weld shape. These are shown in Figure 2.

The usual platform that has no particular stiffening

effect on the shell was redesigned to impart stiffness to replace the horizontal lap joints. The location of these was governed by conditions other than stress, but we were satisfied we gained by the move. Incidentally, no horizontal gussets were used at the stack connections. Diagonal vertical plates were used instead to reduce dirt traps.

The plate dimensions were in general determined by the size of the rolls available to shape them. We used as few welds as possible. It was decided to use one cylindrical section of 8 plates, three long conical sections of 8 plates each, and one short conical section at the top. All vertical joints were in line, contrary to usual practice. There was a good reason for this.

If you roll a cone from a plate originally rectangular, the bottom and top edges of the plate are not in a plane perpendicular to the axis of the cone. It then is necessary either to trim the cone after rolling, or to curve the plate before rolling, if you want such a horizontal plane. When it is desired to have a machined shape on the joint, neither one of the above processes is economical. By keeping the segments in line, the curve of the bottom of the top piece is the same as the curve on the top of the lower segment, and the machining can be done before the shaping. We had only one joint to trim—the joint of the cone and the cylinder. The top plates were made from templates.

ERECTION

The placing of the new shell and platform was scheduled to fit in with the regular relining schedule of the furnace. Materials were ordered from our mills when the management ordered the relining of the furnace. By the time the stock and brick were removed to the hearth, the platforms around the shell were removed, the miscellaneous piping and dirt cleaned off, and changes in the cast house roof support were made.

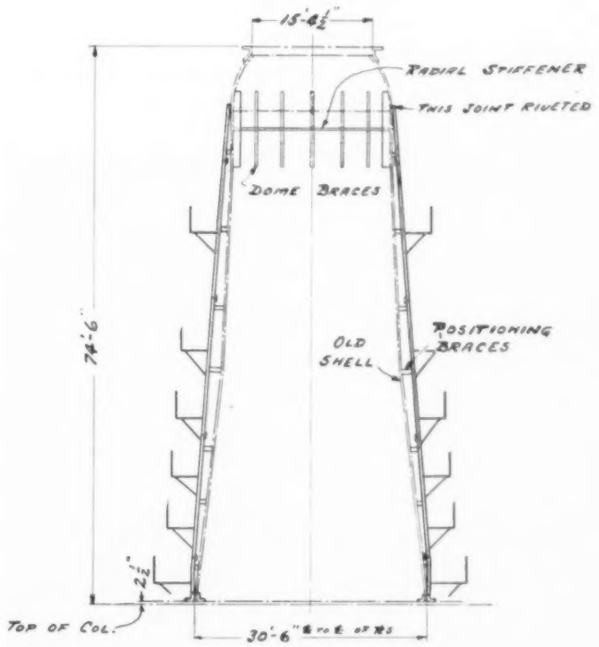
Lines were drawn from 16 points on the dome to 16 points on angle brackets that represented the joint of the cone and the cylinder. Eight of these lines represented the joints. Angles were welded to the old shell at points just below the horizontal joint elevations of the new shell and at points about half way between the joint elevations. These angles were cut off to the line and served as positioners. The short cylindrical section was set up on top of the mantle ring angle as shown in Figure 3. Then the cone segments were erected and bolted together with angle clips. The horizontal buttstrap served to position the shell between the brackets. Angles were welded on where needed to regulate the shell with bolts and wedges (Figure 4). Tacking followed immediately. When the first conical section was placed, regulated and tacked, the bottom horizontal weld was completed, and the vertical joints had two beads of wire which did not complete the weld on one side. When the second conical ring was set and tacked, the second horizontal joint was completed and the beads of weld completed in each vertical weld in the first cone. When the third conical section was set and tacked, the third and fourth welds were completed and all the vertical welds had two beads placed.

The platforms were placed as soon as possible and used as working platforms by the welders. Since these were expected to stiffen the shell, plans were made to have them finished by the time the four lower circles of the shell were set, the horizontal welds completed and two beads laid in all vertical joints.

By this time the salamander and all the brick were out of the furnace. A tight scaffold was then erected inside on the mantle. This was designed to withstand the impact of a possible dropping of a load inside. Above this tight scaffold was erected the motor-driven elevating scaffold regularly used to reline the stack. This was used for all the welding and cutting inside the stack. The total time of the whole job of erecting the new shell and platforms and removing the old was about 56 turns.

The dome braces, consisting of sixteen 2 in. x 12 in. bars, were welded edgewise to the dome and to the old shell inside and a ring one inch thick on 12 in. radial width was welded between the bars at a point about 3 ft. below the dome. While this was being done, templates were made of the last short row of plates and they were made ready. A section of the old shell about 2 ft. high and slightly wider than one-eighth the circumference was then burned out; the rivets were removed and a section of new plate lifted into place (Figure 5). This was bolted to the dome and welded beneath. By sections in this fashion a whole circle of the old shell was removed and the new shell plates were bolted to the dome and welded to each other. When the last row of the new shell was in place, the whole joint at the dome was reamed and riveted. The dome supports were burned out and then the whole old shell removed to within about 3 in. of the mantle angle. This section

FIGURE 3—Sketch showing the method used in the erection of the welded furnace stack.



was bent back to the new shell and welded there. The vertical welds were finished by welding the interior seams completely and finishing the exterior part at the same time. The tops of the butt-straps were then fillet welded.

When the method of erection is understood, it is a little easier to see why we selected the type of joint. Working entirely from the outside we had to provide enough strength to support the top, a matter of nearly 400 tons, and we wanted to do this with as little distortion as possible. On the horizontal welds great care was taken to penetrate directly into the butt-straps to be sure to get what value we could from this ring. The force required to bend a 1 in. plate that is formed in a segment of a circle is considerable, so we were not afraid of distortion in that weld. On the vertical welds with no backing, we had every reason to expect that rapidly filling the outside half of the weld would cause the joint to buckle-in, but once the outside was welded, and this was welded slowly, a good rate of welding inside could be maintained, especially since we did about one-third the outside weld at the same time. At least we were not far wrong. Only one place on the shell showed a noticeable kink, and that could have been avoided. No effort to anneal or peen was made. We have no doubt that there is considerable residual stress in some of the welds, but we feel that they are no worse than stresses developed in a riveted shell by the drifting to shape.

There was little interference with the process of relining. The only direct lost time was the time required to erect and remove the tight scaffold at the mantle because the interior of the stack was finished before the bricklayers reached the mantle. However, if this relining was compared with our usual practice of starting at the mantle and the hearth simultaneously, we lost nearly 8 days' time.

We used as many as eight welders at one time on the stack. It was not desirable to clutter up the furnace floor any further, so the electrical department set up a 1000 ampere machine a short distance from the furnace and the welding cables were run above the floor around the furnace, as planned in advance to reduce difficulties from entangling cables. As far as possible, arrangements were made to have tack welders only available when plates were landed and regulated and bring on the full force when everything was ready for them.

A coated all-position reversed polarity electrode was used. To burn into the butt-straps on the horizontal joints $\frac{5}{32}$ in. size was used, and $\frac{3}{16}$ in. on most of the other work. Regulation of shrinkage was accomplished chiefly by spacing the welders around the joint and having them work in the same direction. Very close inspection was maintained. The assistant welding foreman stayed on the job and the welding foreman spent a lot of time there.

By the method used in transferring the weight while each of the new plates served as a secondary support, they carried very little of the direct load of the top until the 2 in. x 12 in. dome supports were burned off. In an effort to check our assumed loads, bars were set up on each side of the line of cut, and measurements made before and after the cut. There was about .040 in. vertical difference in the measurements. This included not only the deflection of the new shell, but the recovery of the old one. Calculations based on that deflection indicated a load of about 700,000 lb. for the top and downcomers without the bell, lip ring and hopper. The horizontal shift was very small.

Since costs are somewhat difficult to compare from plant to plant and company to company, we list below the hours required and material used, instead of actual cost:

Fabrication of shell plates and platforms:

Structural shop..... 4,400 hours

FIGURE 4—This view of a shell joint shows angles and bolts used for regulating the shell fit.

FIGURE 5—View showing the method of stiffening the dome at the last joint.

Erection in field:

Riggers	2,619 hours
Structural workers	3,238 hours
Welders	2,518 hours
Tearing out old shell and temporary supports:	
Riggers	725 hours
Structural worker	6 hours
Total man hours	13,506 hours
Material used:	
Shell plates	203,000 lb.
Welding rod	4,932 lb.
Platforms, brackets, etc.	90,000 lb.

As you can see from the above figures, the costs were not excessive. Indeed, in this particular case where considerable repairs to the shell would have been necessary and where it was desirable to relocate the coolers, the extra expenditure was very small. Besides providing for the thicker lining, we produced a nice looking job with a very smooth exterior, which we hope will decrease painting costs and corrosion, as well as a much smoother interior which decreased the amount of brick cutting required. We feel that future blast furnaces should be all-welded.

DISCUSSION

PRESENTED BY

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W. S. MORE: In discussing Mr. Gould's paper on welded blast furnace construction, it is rather difficult for me to select any particular phases for discussion. This is particularly true, since at the Bethlehem Plant we have also applied welding to blast furnace construction and maintenance; and, with such application, have been confronted with similar problems of design. To pick out any particular phases as being most important, to my mind, depends entirely on what one is most interested in. Frankly, the design must take into consideration all operations, fabrication, erection and good welding practice, all of which must be carefully studied and must be coordinated, so that in the finished job we may have a 100 per cent installation in strength, in appearance and in cost.

Our Bethlehem Plant application has definitely convinced us that welding has often made very difficult problems far easier; it has greatly simplified design; it has simplified and facilitated shop fabrication and field erection. All of which have resulted in what we feel is better construction and in economies which are really worth while.

Mr. Gould has referred to the replacement of 27 ft. of plate work in our Bethlehem blast furnace "E" stack, and I feel that some of the details of design, erection and welding practice might be of interest.

Our problem at Bethlehem meant the replacement of 25 ft. 8½ in. height of blast furnace "E" stack, which consisted of a truncated cone section, 27 ft. 2 in. inside diameter at bottom and 23 ft. 11¾ in. inside diameter at top. This old section was badly warped and buckled into horizontal corrugations. Now since the top structure of the furnace was to remain intact, and the original lines of the furnace were to be maintained, we faced a problem of putting new sheets into a space occupied by the old sheets. We decided to remove and replace the shell in eight column sections; the installation of each new column section to be complete, welded and riveted, before the adjacent old section was cut away.

Taking into consideration safe load practice, size of plates available from mills and convenience in erection, we decided on the following size of plates:

8 sheets—1 in. plate 10 ft. 4 in. wide x 12 ft. 6 in. high for bottom ring.

8 sheets—1 in. plate 9 ft. 9 in. wide x 13 ft. 9¼ in. high for top ring.

1 in. x 12 in. butt strap plates (outside only).

With these decisions made, the design was developed, and it meant taking into consideration all phases of good welding practice and a thorough consideration of erection problems:

(1) To facilitate erection, welding and to provide a column structure strength, we decided to use outside horizontal and vertical butt straps. Such butt straps served as assembling members for adjacent sheets; served as a backing-up strip for our modified butt weld; and gave us a column stiffness in our final structure.

(2) It was decided to make the modified butt-weld entirely from the inside of the furnace, so a single "V"-welding slot was provided. This meant the beveling of each edge of the plate ½ in. In the erection of the plates we allowed a 3/16 in. opening at the root of the "V"-slot and in consequence had 1 3/16 in. opening at the mouth of the "V"-slot.

(3) Since outside butt-strap was decided on, the butt strap was made of scallop design. Scallops were 3 in. deep and 12 in. long, or on 24 in. centers and all angle cuts were made with 1 in. radius fillet. As the butt strap was to be ⅜ in. fillet welded, our scallop design was adopted, so we would have no straight line weld to allow for straight line cracking if extraordinary stress were set up in the furnace operation.

(4) For the top horizontal connection, new sheet to old sheet, we decided on a lap, riveted joint. Such connection being most adaptable and most flexible from sheet length standpoint.

With the above ideas decided, and with sequence of erection established, we were able to prepare detailed drawings of the various sheets. Such design then allowed us to shop weld 50 per cent of the butt-straps.

The rolling and shop welding of all sheets had to be a careful procedure so that fit when erected was practically perfect. Further to insure such fit, the fabricat-

ing shop set up each ring for final check and if found necessary, rectified before shipping to erection site.

As previously mentioned, it was necessary to remove old shell and erect new sheets in column sections, so that old shell had to be cut out sufficiently to receive the new column of sheets 10 ft. 4 in. to 9 ft. 9 in. wide by 26 ft. 3¼ in. high. Bearing in mind the buckled condition of the old shell, we deemed it advisable to temporarily provide a structural column outside the furnace, to take the load of the cut away section. This structural column spanned the proposed opening and was installed between brackets welded to the old shell, below and above our cut lines. Our bottom cut line was laid out straight and level and was strictly adhered to. One of the problems we had to meet was the fact that the furnace was about 4 in. out of plumb. It was necessary that each sheet be marked with center line and any in or out movement of the sheets had to be made so that this center line moved in a radial vertical plane.

The initial welding bead in the "V"-slot, for both vertical and horizontal joints, were made in step-back sequence. By this method we create heat flow away from the open end, thereby avoiding the tendency to draw plates in an overlapping position at the far end of the welding slot. In building up the weld in the "V"-slot, the various beads were systematically placed in overlapping layers. As stated previously, the butt-strap serves as a backing-up plate at the root of the "V"-slot and gave us a better, cleaner weld, not a true butt-weld.

It might be stated here that this job, and consequently the welding, was done in January, at which time we encountered temperatures of as low as 5 degrees above zero. Extreme care in welding, and detailed welding supervision was therefore necessary.

As stated by Mr. Gould, this work was completed in 16 days or 48 eight hour shifts. The job required 1,364 welder hours and consumed approximately 2,400 lb. of welding electrodes. Such welding electrodes being 3/16 in. diameter, and were covered rods suitable for vertical welding.

Another interesting welded construction in our Bethlehem blast furnaces was the installation of welded steel hearth jackets. To better illustrate the advantages and economies of welding in this type of construction, I would like to give some of the details of four steel hearth jacket installations. In November, 1929, we installed in our blast furnace "E" our first steel hearth jacket, which was of riveted construction with inside and outside butt-straps. The design consisted of the following:

Inside diameter of jacket—25 ft. 2 in.

Jacket consisted of eight sections of 1½ in. plate, 11 ft. 5 in. high and 9 ft. 11 3/16 in. long with inside and outside butt-straps of 1 in. plate.

This riveted construction required 5,910 holes to be drilled or punched, fitted and reamed to take 1,970 1¼ in. rivets.

In December 1936 we installed a steel hearth jacket in our blast furnace "A."

In February 1937 we installed a steel hearth jacket in our blast furnace "B."

In December 1937 we installed a steel hearth jacket in our blast furnace "F."

All of these three steel hearth jackets were 26 ft. 2 in. inside diameter, and all were of butt-weld construction, with no butt-straps. Each of these jackets was made of five sections of 1½ in. plate, 16 ft. 6¼ in. long and 10 ft. 4⅞ in., 9 ft. 5⅝ in. and 10 ft. 9½ in. high, respectively. The welding design was of the double "U" type. All welding was done in the step-back sequence; each joint being worked on by two welders, welding simultaneously inside and outside. Each of these steel jackets were welded completely in 96 welder hours or less.

Comparing the two designs, riveted vs. welded: the drilling or punching, fitting and reaming of 5,910 holes for 1,970 1¼ in. rivets and the driving of these rivets as against the machining of ten plate edges to form the double "U" welding slot and the 96 welder hours for completed assembly.

The contrast is so great that the application of welding is just about compulsory. Right now, we are preparing to install in our blast furnace "G," a 2 in. steel plate hearth jacket. This will be made up of eight sections 13 ft. 5 in. high and 10 ft. 15/16 in. long, and of course designed for welded assembly.

In conclusion, let me again say, our welded construction applications have shown welding to give us a simpler design which simplifies and facilitates shop fabrication and field erection; all of which result in really worth while economies and give us a neater and we feel a better construction.

CARL HOFFMAN: "F" furnace was originally a thin walled furnace, having slightly less than 20 in. of brickwork at the thinnest section. We did get as high as 650,000 tons on the lining, but the thin inwall resulted, early in the campaign, in the use of water sprays, and we also had several buckled shell plates.

We wanted a thicker inwall but we did not want to change the lines of the furnace for she had done very good work on her old lines, averaging 800 tons of iron per day with a coke rate of 1700 lb. and flue dust production of 50 lb. per ton of pig iron. We also did not want to dismantle the top, so about the only way the job could have been done was as Mr. Gould described it.

A very good job has been done and is satisfactory in all respects. The furnace has been in blast for four months and there has been no sign of any trouble whatever. However, we feel that a longer test is required before drawing conclusions concerning an all welded blast furnace shell.

ARTHUR G. MCKEE: In the first place, I want to compliment Mr. Gould and all those who are associated with him on this difficult job which they have accomplished in the replacement of a blast furnace shell without taking anything down, and with complete success maintaining the top structure, the down-comers, etc., in place, while this new strong shell was erected and completely welded. This was a very notable job and one that is worthy of high commendation.

The aspect of this job which interests me is how the cost will compare when we get through with a completely welded shell job. We are engineers and builders, and in the first place we have to sell a job. I very much desire to get more complete information, not only as to the erection cost of this job, which cost is doubtless higher because of the fact that you are replacing an old shell under difficult conditions, but the comparison of the cost of doing this job by welding with the cost of doing a blast furnace shell under ordinary conditions

with riveted construction. I don't know how it will compare, and unfortunately we cannot make correct comparisons between this job and a new shell on account of the peculiar circumstances. I sincerely hope that we may shortly get comparisons which will give us information as to the relative costs.

Of course, if you have complete blast furnace shells, then that means a welded mantle plate if this construction is used all the way through, and you then get into the welding of heavy sections, welds that are 2½ or 3 in. thick, and the problem of stress relief becomes an important one. Personally, I am of the opinion, and our organization is of the opinion, that welding is destined to take the place of riveting to a large extent, if not entirely, in blast furnace construction, and I am watching the work that is being done in this direction with the greatest interest, and I hope that very soon we may have full information on which we can design intelligently and predict costs accurately on welded construction, which should be very much better than riveted construction, unless unforeseen faults and defects develop from practice in the use of welding construction.

L. F. COFFIN: In the article Mr. Gould referred to on the German all-welded blast furnace, there is a rather interesting comparison of the relative strengths of riveted and welded joints, in which they point out, according to their results, that their welded joints were inherently stronger than the riveted joints.

L. J. GOULD: I might point out one thing. If you hope to eliminate that possibility of cracking by welding the stack, you are likely to be disappointed. We have had cracks in the top of our stacks, near the stock line, and they are sometimes right in the middle of a plate. On this particular furnace mentioned, we were a little bit in a hurry in taking down some coolers and knew the shell wasn't any good. We set off a charge a little bit too close. The fracture of that plate right in the middle looked like a piece of tool steel. I think the reason is that the worst aging temperature is somewhere around 180 or 200 degrees, and our shells are frequently at that temperature.

Do not forget that in rolling the shell to shape you put considerable strain on it. You put the strain on it and then apply the heat, and this is the ideal condition for age-hardening. It happens in the middle of plates, and you can't eliminate that by welding.

Mr. McKee seems to feel that the welding of heavy plates on the mantle may be the limit on an all-welded furnace. Welds 3 in. thick are not uncommon in mill parts, and in many instances are not stress relieved. The real difficulty will be to sell the idea to furnace men and engineers that such welds are safe. The attitude that welds must be as strong as the parent metal, or as some optimists say, stronger, did much to develop the welding rods, procedure, and equipment we have today, and is an excellent viewpoint for the research man, but does hold up the advance of the use of welding.

You can assign a lower value of stress to the weld when the work is done under imperfect conditions. It is an extremely bad weld these days that does not develop a joint efficiency comparable to riveted joints, especially when the plates are thick. There is still this good old-fashioned idea to consider: "Put the joint where the stress isn't."

ARTHUR G. MCKEE: I have made careful observation as to the splitting of the furnace shells over many years. Of course, conditions are very hard to determine after the thing is split, but as a rule I am satisfied that the furnace shells that split are ruptured on account of strains due to the brick work, or else because there is a sudden change in temperature on one side which throws a terrific strain into a shell.

I have known of three stove shells in the same group to split under conditions where the weather turned suddenly extremely cold with rain and sleet and a high wind, which caused a rupture of all three on horizontal seams, but in all the cases that I know of, including this one, there has been initial stress in the shell due to the fact that the brick work was pushing on the shell at some point.

I personally wish that we might find a better material for packing between brick work and shell. Loam has been used for many years. It seems to be the favorite material, but the fact of the matter is that, as the furnace lining dries out, the moisture is driven out into the loam, making it wet and soggy, and then it is dried out, and it bakes until it is almost as hard as brick, with absolutely no compressibility to relieve stresses in the shell due to the expansion of the brick.

I wish we could find some material which is sufficiently refractory to use as a packing and which would at the same time be sufficiently compressible so that as the brick work expands it will compress the packing without putting undue stresses on the shell. I think that is a matter of very great importance. We have pretty well eliminated the rupture of stove shells by better design and better means for preventing stresses from the expansion of the brick. Now the blast furnace shells are still bursting, and I think that we should very carefully study the possibility of using some other compressible material which is refractory and which will prevent the gases from running up back of the brick work in case of rupture of the brick work. I don't know what would be best, but I think that quite possibly fibrous asbestos would serve the purpose very much better than anything we have. The use of a mineral wool might be very much better than the loam that is so generally used.

This is a subject which I think ought to be given very careful study to determine what is the best packing to prevent the strains being put into the shell by brick expansion, and if we can do that I think we will eliminate the ruptures of blast furnace shells, excepting possibly in cases where there is a very sudden and extreme change in temperature with high wind and sleet or wet snow.

ELECTRICAL EQUIPMENT *for the* EDGAR THOMPSON *Slabbing Mill*

By R. H. WRIGHT and B. J. AUBURN

WESTINGHOUSE ELECTRIC & MFG. COMPANY

EAST PITTSBURGH, PENNA.

Presented before A. I. S. E. Pittsburgh Section, October 24, 1939

▲ SLABS have always been a common product of primary reduction mills, and both blooming mills with shaped rolls and universal mills with smooth horizontal and vertical rolls have been used for many years for slabbing work. One of the oldest mills operating in the Pittsburgh district is a universal slabbing mill driven by two engines; one engine for the horizontal rolls and one engine for the vertical rolls. While the basic principles of operation are old, the present day demand for greater quantities and larger sizes of slabs has greatly augmented the steel makers' problems in the selection of primary reduction mills and their drives.

Due chiefly to the requirements of the Irvin Works, the Carnegie-Illinois Steel Corporation needed a mill with an average output of 200 tons per hour of slabs up to 8 in. x 60 in. from ingots weighing up to more than 35,000 lb. each. After a study of a number of existing mills used chiefly for slabbing work certain conclusions were reached regarding the new mill. These conclusions were:

1. That a universal mill with separate drives for the horizontal and vertical rolls was best suited for the requirements.
2. That a 10,000 hp. drive would be required for the horizontal rolls, preferably with a separate motor for each roll.
3. That it was desirable to make provision for heavier side drafts than could be made in most universal mills in operation at that time.
4. That provision should be made for side draft in either direction of travel. Some mills had this provision and some did not.
5. That the principal auxiliaries should be operated with variable voltage control.

FIGURE 1—In this view of the mill, the housing for the vertical roll motor is shown at upper right.

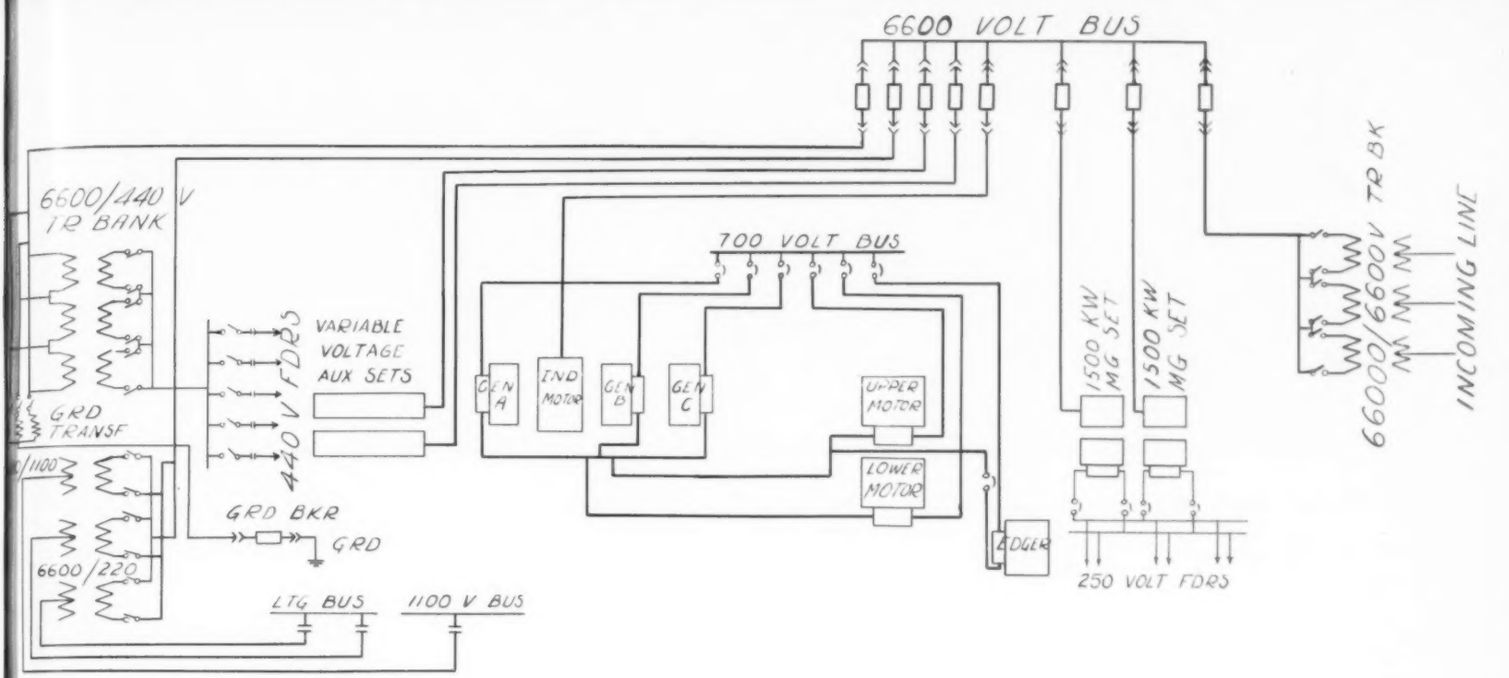


FIGURE 3—Schematic diagram of main power circuits of the complete electrical system for the slabbing mill.

6. That there was an opportunity to improve the overall performance by careful study and coordination of mechanical design.

The use of variable voltage auxiliaries and a 10,000 hp. twin-motor drive operating in parallel with a separate edger drive did not present any new problems. However, to provide for heavier side drafts it was necessary to depart somewhat from previously established practice. Because of the inherent limitations of right-angle gear drives, 2,500 hp. was the maximum power which previously had been applied to the vertical rolls of a universal mill. Even assuming that all mechanical limitations could be removed, a very cumbersome and expensive vertical roll drive would be required if all conceivable requirements for side work were taken care of in the vertical rolls. Accordingly the mill was designed for 65 in. lift of the top horizontal roll and the ingots are brought to the mill on edge and the heavy side drafts are made in the horizontal rolls in the first four passes. The ingots are then turned 90 degrees and simultaneous reductions are made in the horizontal and vertical rolls until the desired section has been secured.

It was decided that the vertical roll gearing could be designed to permit the use of a 3,000 hp. edging roll drive. To insure maximum mechanical efficiency of the vertical roll assembly, a combination bevel and reduction gear unit with anti-friction bearings, all carried in an oil tight case, is provided for each vertical roll. The vertical rolls are 36 in. in diameter which is considerably larger than had been used previously. The combination of a larger motor, larger rolls and special high efficiency gearing has increased materially the amount of draft which can be taken in the vertical rolls. The improvement in gearing is very beneficial and allows a 3,000 hp. motor to do work which would require a much

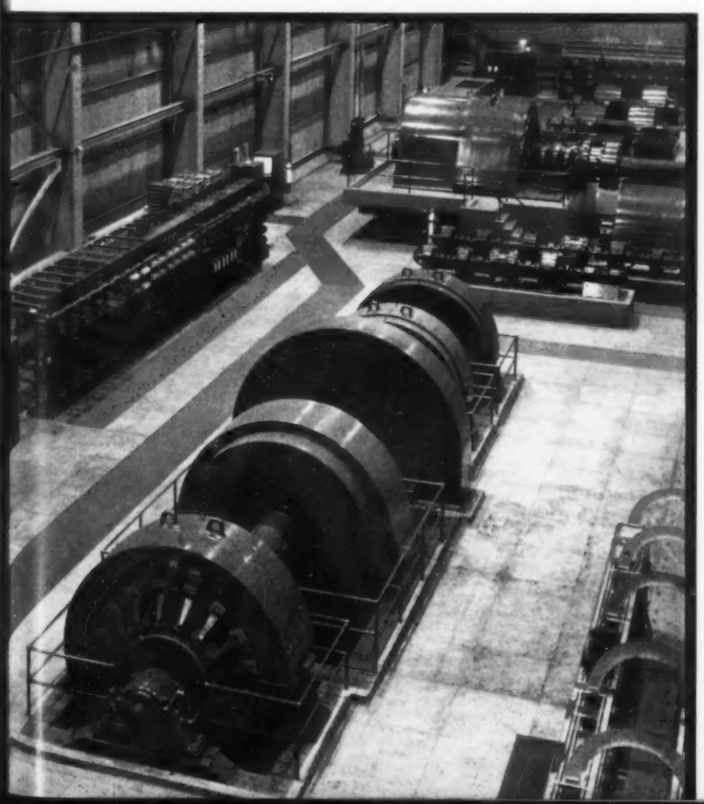


FIGURE 2—General view of motor room, showing twin main roll drives in background, motor-generator set in foreground.

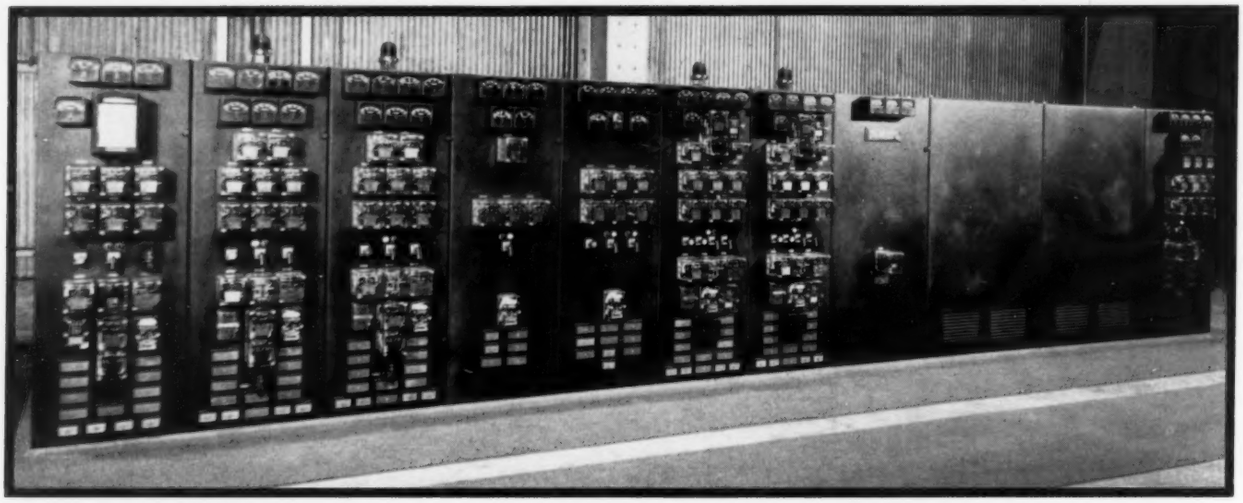


FIGURE 4—The 6600 volt circuits are controlled by metal clad switch-gear with breakers of 250,000 kva. rupturing capacity.

larger motor with the open gearing used with the old steam driven mills.

The ability to take vertical roll drafts in either direction is largely a matter of arranging the mill and pulpit so the roller can see the bloom at all times; having the vertical rolls large enough so that there is no fear of roll breakage when the bloom strikes at an angle and providing suitable range of speed control for the vertical roll motor. The pulpit for this mill is over the tables on the vertical roll side. The vertical rolls are in the same housing as the horizontal rolls and the roller has a clear view of both sets of rolls at all times. The 36 in. diameter vertical rolls have ample strength to resist impact of the bloom and by their size tend to hold the bloom straight as it passes through the mill. The 3,000 hp. vertical roll motor has a 3:1 speed range which together with suitable control permits vertical roll drafting in either direction over the range of speeds used in slabbing.

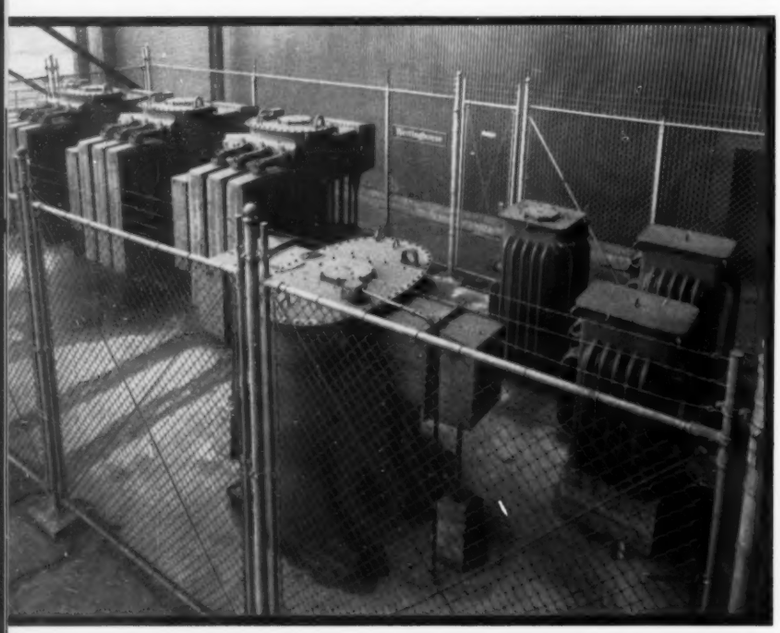
These strictly mechanical features have been mentioned because they play an important part in the successful operation of the electric drives for a universal mill and it is only by coordination of mechanical and electrical design that maximum results are obtained.

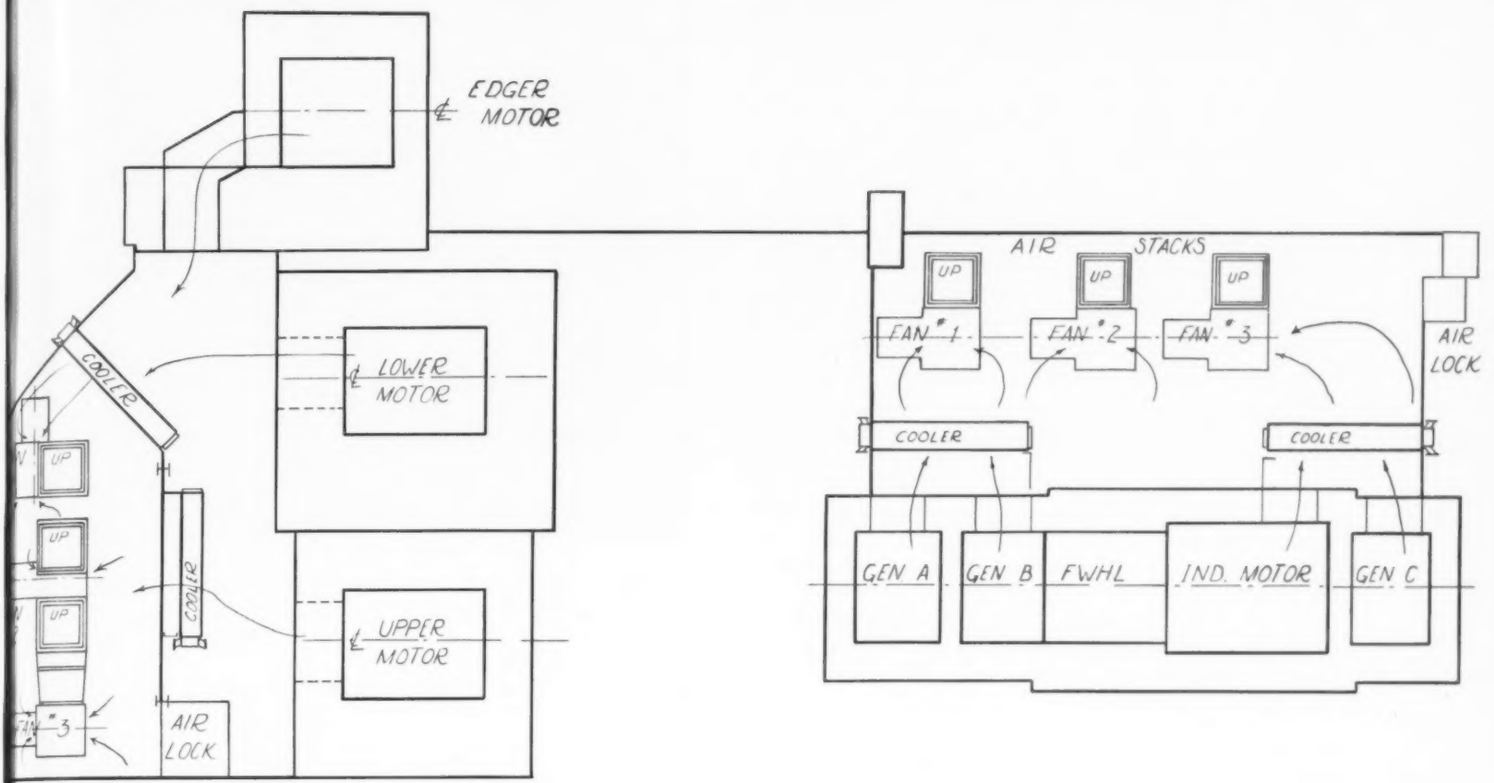
Figure 1 is a view of the mill and pulpit and the housing for the 3,000 hp. vertical roll motor. Provision has been made for the installation of a second pulpit on the opposite side of the mill, to be used when the mill operates as a bloomer.

Figure 2 is a general view of the motor room. While there are only three main drives, it will be noted that the size of the motor room approaches that of a large hot strip mill. The complete installation is the largest of its kind and the engineering and construction work involved major problems. The contracts for the electrical equipment included electrical erection, motor room lubrication system installed and water piping, coolers, fans and steel compartments for the cooling and ventilating system.

The arrangement of the complete electrical system is shown schematically in Figure 3. The mill is operated on 60 cycle purchased power which is brought into the plant by a 66 kv. overhead line. A 12,000 kva. delta-delta step down transformer bank reduces the potential to 6,600 volts for the main circuits and a 3,000 kva. delta-delta 6,600/440 volt transformer bank supplies the a-c. auxiliaries. Both transformer banks are equipped with automatically controlled fans to give increased capacity when required. Lighting circuits are supplied through two 100 kva. single phase transformers. The 6,600 volt circuits are controlled by a metal clad structure with vertical lift oil circuit breakers having 250,000 kva. rupturing capacity. This structure is shown in Figure 4. For miscellaneous d-c. auxiliaries, two 1,500 kw., 250 volt synchronous motor-generators

FIGURE 5—The grounding transformer in the foreground insures positive action of ground and differential relays on the delta-connected transformer banks.





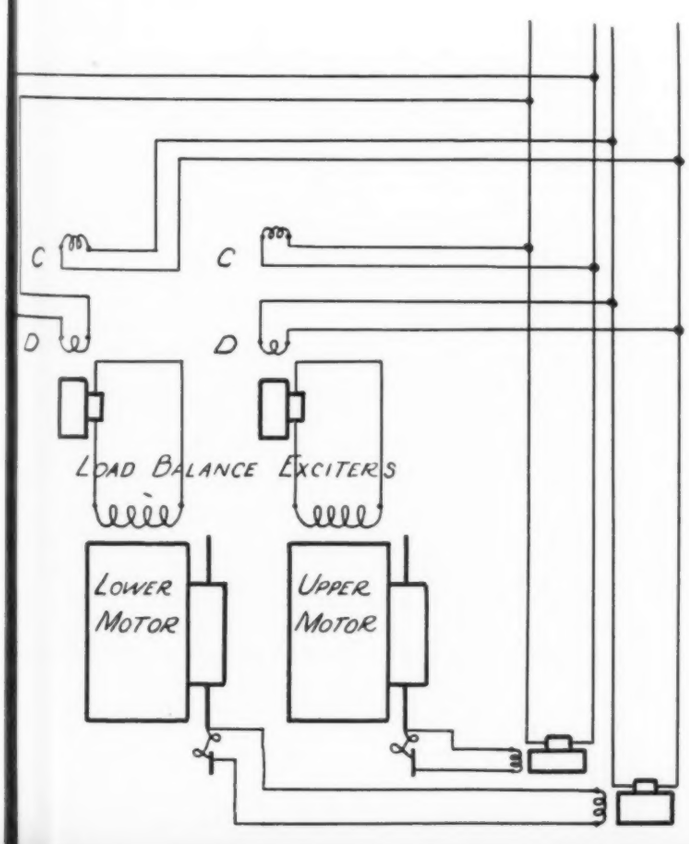
with automatic substation type d-c. switching are installed in the motor room.

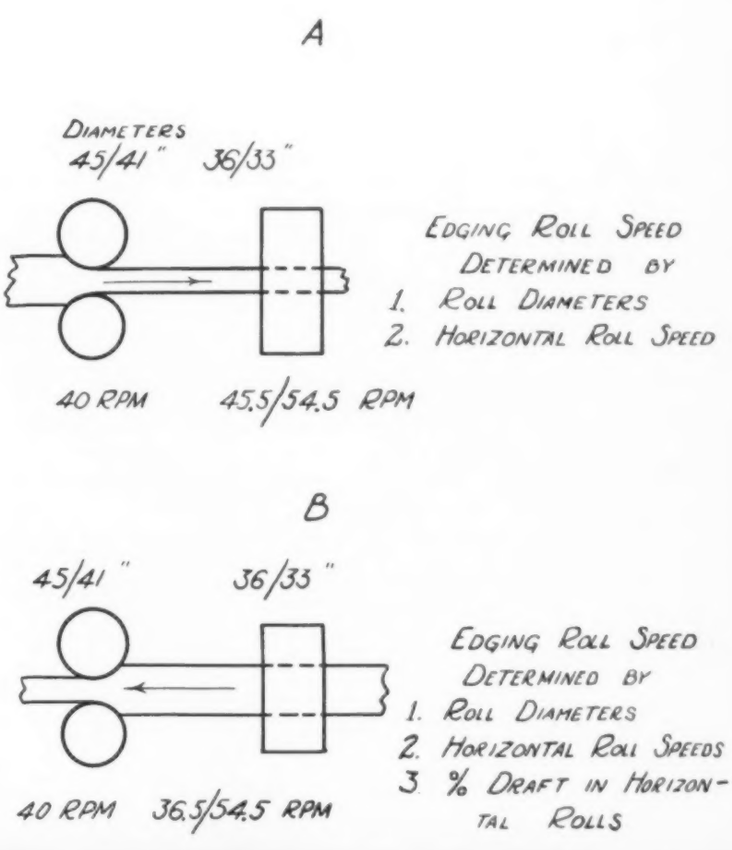
Since the transformer banks are delta connected, a grounding transformer has been provided to insure positive action of the ground relays and differential relays. The grounding transformer is shown in the foreground of Figure 5. This photograph also shows the

FIGURE 6—Sketch showing general arrangement of downdraft recirculating ventilating system for reversing motors and flywheel set.

FIGURE 7—Schematic diagram showing method of balancing the loads of the two horizontal roll motors. *(Bottom Left)*

FIGURE 8—Sketch showing main roll and edging roll speed elations which must be provided for. *(Bottom Right)*





auxiliary power and lighting transformers. All connections to this group of transformers are made with lead covered cable through special enclosed terminal chambers. The delta connections for the 6,600 volt windings of the main transformers and the 6,600 volt and 440 volt windings of the auxiliary transformer bank are formed inside the substation through disconnecting switches. This arrangement facilitates removal of one transformer for open delta operation.

Direct current power for the mill main drives is supplied from a 352 rpm. flywheel motor generator consisting of three 3,500 kw., 700 volt generators operating in parallel, a 7,500 hp. wound rotor induction motor and a 200,000 lb., 15 ft. diameter steel plate flywheel. A dynamic braking generator and control are provided for use whenever it is desired to bring the set to rest quickly.

The drive for the horizontal rolls consists of two 5,000 hp., 40/80 rpm., 700 volt reversing motors. One motor is connected directly to each roll. These motors are single armature machines and are mounted on 94 in. centers. In two previous installations double armature motors had been used in order to keep the center distance down to 83 in. Experience with these earlier installations had shown that an increase in center distance would not be detrimental, so advantage was taken of the greater simplicity of single armature motors. The general design of the motors is conventional except for the type of enclosure. The commutator and front pedestal are completely enclosed by a steel housing. This housing connects with a fan suction chamber in the basement. The end bell at the rear end has a screened circular opening with a diameter about equal to that of the armature. Air from the motor room is drawn by suction into the motor through this opening and after passing through the windings is discharged into the pit beneath the motor. The warm air is then drawn through surface coolers and the cooled air delivered to the motor room by the fans.

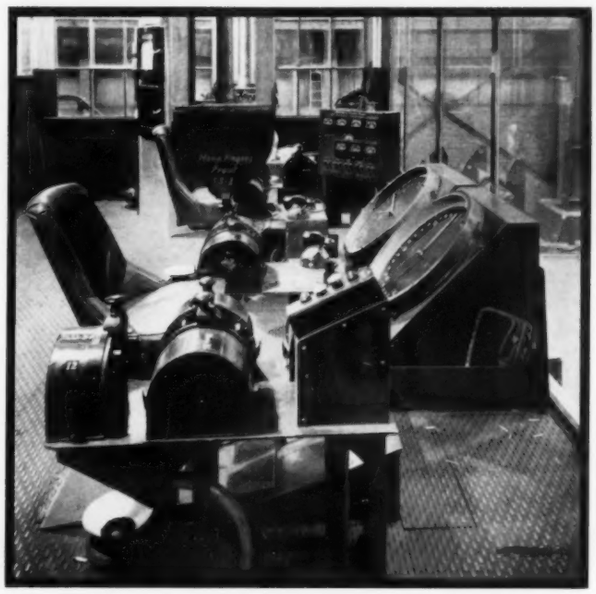


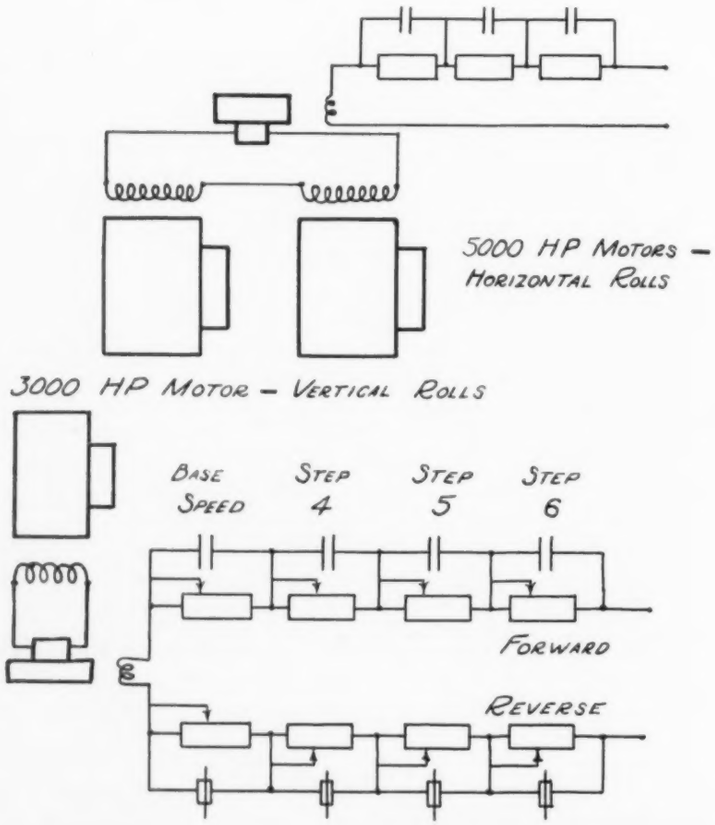
FIGURE 10—Electrically operated screwdown indicators are centrally mounted in the modern well-designed pulpit.

The motor for the edging rolls is rated at 3000 hp., 60/180 rpm., 700 volts. This motor has the same type of enclosure as the horizontal roll motors and is ventilated by the same fans.

Figure 6 shows the general arrangement of the down draft recirculating type ventilating and cooling system for the mill motors and flywheel motor-generator. The 1500 kw., 250 volt motor-generators and variable voltage sets are ventilated in the same way by separate fans and coolers. The cooling water temperature may be as high as 85 to 95 degrees F. in the summer months, so it was necessary to provide extra cooling surface in order to keep the motor room temperature within reasonable limits in warm weather. While such cooling water conditions impose a considerable handicap on a recirculating system, it was felt that the advantages justified such an installation. The effect of an increase in cooling water temperature is illustrated by the increase in cooling water requirements. With 85 degree water, the rated absorption capacity of 3300 kw. can be obtained with 1550 gal. of cooling water per min., while with 95 degree cooling water, 4250 gal. per min. are required to obtain the same outgoing air temperature. The cooling water, of course, is not wasted but is used in the mill after passing through the coolers.

The three reversing motors and the three main generators are all paralleled on a common bus, as indicated in Figure 3. The equalizing cross connections between the generators are arranged so that any generator can be cut out in an emergency. The 3,000 hp. edging roll motor can be disconnected from the bus if

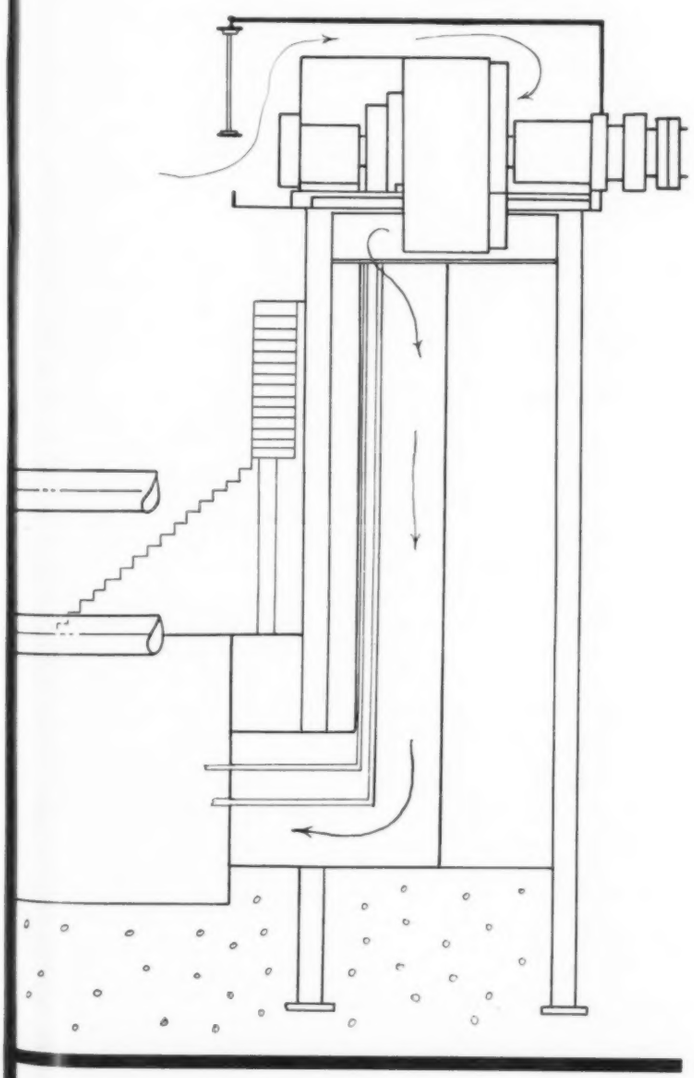
FIGURE 9—Diagram showing reversing motor shunt field connections which enable edger speed to match main roll speed.



it is desired to operate the mill as a bloomer, using only the horizontal rolls.

No provision is made or required for matching the speeds of the 5,000 hp. horizontal roll motors. Satisfactory parallel operation of these motors is secured by equalizing the loads. With such an arrangement it is not necessary for the mill rolls to have exactly the same diameter. The method of equalizing the loads is shown schematically in Figure 7. Each 5,000 hp. motor has an auxiliary load balance winding, each connected to a separate exciter. This winding is accumulative with respect to the main shunt winding. The load balance exciters each have a differential field (D) and an accumulative field (C). The fields of the load balance exciters are connected to small pilot series exciters in the manner shown by the diagram. The accumulative field windings are more powerful than the differential windings, thus making it possible to secure any desired degree of compounding of the main motors. With this arrangement any tendency for one motor to take more than an equal share of the total load increases the field strength of that motor and decreases the field strength of the other motor, thus re-establishing a balance of load currents.

FIGURE 11—The elevated mounting of the edging roll motor required careful engineering design to eliminate vibration.



The control for a universal reversing mill must also include means for securing correct relations between the speeds and loads of the main and edging roll drives. The conditions which must be provided for are illustrated by the sketches in Figure 8. As shown by sketch A, when the slab is moving from the horizontal rolls toward the vertical rolls the speed of the edging rolls is determined by the relative diameters of the rolls and the speed of the horizontal rolls. If the range of roll diameters is 45 in. to 41 in. for the horizontal rolls and 36 in. to 33 in. for the vertical rolls, the speed of the edging rolls may be anywhere between 46.5 and 54.5 rpm. for 40 rpm. of the main rolls. When the slab is moving in the opposite direction, as illustrated by sketch B, the speed of the edging rolls must be compensated also for the draft in the main rolls. For horizontal roll draft between 0 and 20 per cent, the edging roll speed may be anywhere between 36.5 and 54.5 rpm. for the above ranges of roll diameters. The range of edging roll speed adjustment can be reduced if the speed of the horizontal roll drive is adjusted to compensate for changes in the diameter of the horizontal rolls. However, this introduces additional control adjustments and for the sake of simplicity this installation is designed so that all adjustments for variations in roll diameter are made on the edging roll drive.

The horizontal roll draft may very from less than 5 per cent to as much as 20 per cent. It is seldom possible or desirable to operate a slabbing mill on fixed rolling schedules, so there is no easy way to predetermine the exact percentage of draft in any given pass. Consequently there is no simple way to adjust the speed of the edging roll motor before the pass to compensate for horizontal roll draft. However, such a procedure is not necessary. The arrangement used is to heavily compound the edging roll motor and set the no load speed in one direction about 10 per cent slower than in the other direction. The shunt field connections used for this purpose are shown schematically in Figure 9. The horizontal roll motors have a fixed base speed and three fixed speeds above the base speed. The same number of speed control steps are provided for the edger motor. Rheostats are provided to adjust the base speed of the edging roll motor in each direction of rotation. Also there are rheostats for each rotation for each of the three weakened field steps. The rheostats for adjusting the base speed have indicators and three sets of numbers which show where to set the step rheostats for each base speed. These rheostats are adjusted only when the roll diameters are changed. The use of adjustable step resistors insures that the percentage change in edger motor speed will be approximately the same on each step as for the horizontal roll motors. All of the rheostats are in the motor room on the control panel and no speed adjustments are made by the pulpit crew.

Figure 10 is a view of the pulpit. The screwdown indicators are electrically operated and are mounted in the pulpit between the operators' stations.

One of the major construction problems was the

determination of the location and method of mounting the edging roll motor. To locate this motor in the motor room, a large spacer gear would have been required if serious interference with the horizontal roll motor foundations were to be avoided. To mount the motor in the mill in the location finally chosen it was necessary to provide a special steel and concrete structure. A vertical section of this structure giving the location of the leads and air passages is shown in Figure 11. A heavy steel structure was first erected. Concrete was then poured in all the available space to eliminate the possibility of vibration. The top of this structure is about 25 feet above the motor room floor and one side of the motor base has considerable overhang but nevertheless the structure and drive are completely free from vibration.

The mill has been in operation about 18 months. Most of the rolling has been on slabs of medium width and the main roll drafts have been moderate in order to avoid damage to the steel. It has not been necessary to roll at high speeds in order to obtain high output; 50 rpm. being the maximum speed used on the horizontal rolls. The very satisfactory performance of the complete installation may be attributed to the excellent design of the mill, the use of variable voltage auxiliaries and the careful consideration of mechanical and electrical design of the drives.

DISCUSSION

PRESENTED BY

M. H. MORGAN, JR., *Project Engineer,* Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.

R. H. ELLIS, Electrical Engineer, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

T. R. RHEA, Industrial Department, General Electric Company, Schenectady, New York.

JAMES FARRINGTON, *Electrical Superintendent,* Wheeling Steel Corporation, Steubenville, Ohio.

J. I. KASPARI, *Electrical Engineer,* Weirton Steel Company, Weirton, West Virginia.

R. H. WRIGHT, *Steel Mill Engineer,* Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

M. H. MORGAN, JR.: In response to questions which have been asked me in connection with the installation of our slabbing mill just described, I will try to outline the major considerations involved in the adoption of certain unusual features.

There are other twin drives, of course, but few enough so that they could not yet be considered commonplace. Comparing a twin main roll drive of this size with a pinion stand drive of equal capacity, it will be found that the twin arrangement is shorter overall from center line of mill to outer end of motor shaft, and that, even though shorter, there will be a maximum spindle angle of around five degrees as compared to an angle approaching 9 or 10 degrees for the other. The shorter drive will allow either a narrower mill and motor room or a better utilization of an equal space. Heaviest parts of the twin drive will not be as heavy as the heaviest of the single motor pinion stand drive, allowing substantial reduction in crane and crane runway capacity. Accurate cost comparisons are difficult to make but, as made, showed little difference.

Finally, the twin drive was actually the most conservative choice because, while there are two such drives in this country at our South Works in Chicago, and one in Russia, there are no 10,000 hp. single unit reversing pinion stand drives, and such a one would, therefore, be a totally new design. The only remaining question then was as to the effectiveness of the load division and speed control features for upper and lower roll motors. A short period of observation suffices to show that it is adequate and our own experience confirms this impression.

It will be noted that the 3,000 hp. edger motor has a lower base speed than previous installations, and that the two 5,000 hp. horizontal roll motors are single-unit motors with one commutator each instead of double armature designs as was formerly employed. The nature of the rolling operation performed requires both horizontal and vertical drives to maintain the same speed relationship at all times so that the drive as a whole starts, accelerates and reverses at the fastest rate obtainable from the most sluggish unit—the edger motor. It was found that a slower speed edger motor would have better peak load capacity and faster reversal with correspondingly faster possible reversal for the mill as a whole, and it was also made evident that single armature 5,000 hp. horizontal roll motors would still reverse faster than the slower edger motor, would offer some price advantage and would require maintenance of two less commutators. The slow speed edger motor with single armature main roll motors was accordingly adopted and has worked out as expected in the finished drive.

The edger motor location and the arrangement and construction of its base is unusual as is shown in the pictures in this paper.

The vertical roll stand is located as close to the horizontal rolls as dimensions of the two housings will permit to insure the front end of the piece entering the one set of rolls accurately after leaving the other. The two are, in our case, on 7 ft. 4 in. centers so that, if the edger motor were mounted in the usual way in the motor room on the center line of that stand, it would overhang the 5,000 hp. motors by such an amount that it would be difficult, if not impossible, to obtain an adequate base, and when obtained would interfere seriously with accessibility of the 5,000 hp. motors. An alternative was considered consisting of a gear set which would in effect offset the edger motor, but was rejected because: (1) the edger stand included the equivalent of a vertical pinion stand so that the drive shaft extending from the mill was to run at motor speed and the external gear set would not serve any essential purpose; (2) the added gear set would involve additional power losses and would increase the inertia of the drive; and (3) there would, of course, be added cost for the gear set and its foundation.

The problem remaining was to obtain an adequate

motor base approximately 26 ft. high with severe footing restrictions imposed by manipulator cross shafts and horizontal roll spindles, and this was done with a steel and concrete structure of sufficient mass and stiffness to be quite free from vibration.

Our use of a re-circulating type of ventilating system was based on the fact that the motor room is located not far from both boiler house and Bessemer converters, and we felt that the less air taken in, the less dirt would come with it; the best cleaners being still somewhat less than perfect. Further, the use of tubular water to air heat exchangers for recirculated air will positively hold the motor room temperature within a definite and not very large amount above that of the cooling water available due, chiefly, to the fact that, as the motor room air temperature tends to rise, the temperature differential across the exchangers rises and the heat dissipating capacity of the cooling system is rapidly increased. In this instance, the system was designed to hold a 40 degree C. (104 degrees F.) air temperature with the warmest river water temperatures expected, and actual air temperatures in the motor room have not exceeded about 90 degrees F.

Water discharged from the coolers is re-used in the scale handling system of the mill so that the requirements of the cooling system do not add to the plant water consumption.

Professor Trinks of Carnegie Institute of Technology has previously called attention to the fact that in a mill of this type the piece is actually in the mill rolls only about one-fourth of the time, and for three-fourths of the time it is being handled by the front and back tables, manipulator or waiting for the screwdown. This fact is easily verified by observation and its significance is that any effort to increase tonnage is three times as effective when applied to the auxiliaries as if to the mill. This was the basic reason for using variable voltage control on the auxiliaries named as well as the slab shear.

Our manipulators, tables, etc., were very much heavier than previous equipment for similar work and the handling of them consisted largely of rapid acceleration and quick reversal which for heavy parts imposes peak loads on the drives. Variable voltage drive permits utilization of the full capacity of the drives for such work and observation of mills equipped with it seemed to indicate that operators were able to handle the piece with greater facility and precision than in mills not so equipped, and that there was some advantage in lessened mechanical and electrical maintenance of equipment so driven. In practice, our mill operators credit the performance of these variable voltage auxiliaries with a substantial share in the smooth performance and sustained high tonnage output of the mill.

R. H. Ellis: Mr. Wright and Mr. Auburn are to be congratulated on a paper which explains very clearly the intricate design of the major drives involved with this undertaking. Mr. Morgan has very ably discussed the control details covering all the auxiliary drives. He did not mention the fact that, under his direction, each auxiliary drive was given a very complete and comprehensive study in regards to the inertia loads to which the motors would be subjected. An empirical formula was established, after a study of many existing units, which was used to determine the size of each motor. It might be of interest to know that this formula was as follows:

> Using 40 per cent of the maximum torque of the mill type motor the theoretical acceleration time must be in the neighborhood of one second or less before the motor chosen was approved.

Regarding the mechanical features of the mill, a complete article by M. P. Sieger has been published in the Iron and Steel Engineer for November, 1939, and covers this phase of the mill completely.

Another electrical development of note incorporated in this mill is the use of selsyn indicators for both the edger rolls and the mill screwdown. The use of these units permits the screw indicators to be placed in the mill pulpit close by the operators. This provides an indicator which the operator can see very easily and prevents his vision from being interfered with by steam rising from the mill. A note of warning should be issued in the use of these equipments. A source of uninterrupted power should be supplied and repeated routine inspection should be established.

T. R. Rhea: On a slabbing mill of this sort, the main drive equipment, the mill crew and the auxiliaries form a team for producing steel. I am sure it will not detract from the paper on the main drives to give a few words on the unusual features of these main mill auxiliary drives.

The last four or five blooming or blooming-slabbing mills installed in this country have all had their main auxiliaries equipped with Ward-Leonard control. This Edgar Thomson slabbing mill is among those mills so equipped.

The motors equipped with Ward-Leonard control are:

a. Screwdowns. The screwdown consists of two motors, and each motor has its separate generator.
b. Front and back live tables. Each table has two motors connected permanently in series, with a separate generator. That is, one generator for each table.
c. Right and left side guards, front and rear. Each of the four side guards has a separate motor and a separate generator, making a total of four motors and four generators. The side guards on the front and rear of the table are mechanically connected together so that they move simultaneously, with provision for mechanically uncoupling them.
d. Slab shear. This is driven by two motors, each with its separate generator.

These main auxiliaries are supplied from two auxiliary motor-generator sets, and the various motor armature circuits are equipped with knife switch transfers so that all auxiliaries can be operated at half speed even though one complete motor generator set is down.

These generators have special characteristics of the three field or shovel type, such that the motors, which are solidly connected to them, may stall at approximately 250 or 300 per cent torque without injury and will run at approximately double speed with double voltage at no load. These characteristics are very desirable on these hard-worked auxiliaries. For example, on the screwdowns, high torques are available for small quick movements of an inch or two, and high speeds are available for long movements of the rolls. These characteristics applied to the side guards permit the side guards to squeeze the slab and stall with entire safety to the motors and mechanical equipment. Such

characteristics permit the slab shear motors to slow down as the knives bite through the slab. If necessary, they may stall when cutting a cold slab without injury to the electrical or mechanical equipment.

The principal mill auxiliaries of the following mills have this type of special Ward-Leonard control:

a. Inland.....46 in. slabbing mill, 1936
b. T. C. I.....46 in. slabbing mill, 1937
c. Great Lakes Steel.....46 in. slabbing mill, 1937
d. Edgar Thomson.....45 in. slabbing mill, 1937
e. Weirton Steel Co.....35 in. structural mill, 1939

In fact, all blooming and slabbing mills installed in the United States since the initial installation in 1936 at Inland have had this type of main auxiliary Ward-Leonard control.

Its advantages over magnetic control for these very hard-worked auxiliaries can be summarized as follows:

a. It is easier on mechanical equipment because the torque is limited to a definite safe value and this results in less breakage and maintenance of mechanical equipment.
b. Very little and very simple control. There are no main current carrying contactors, since the generators are solidly connected to the motors. The control handles only field currents. This means that the maintenance and lost time due to control difficulties on ordinary magnetic controlled systems is practically eliminated.
c. Higher running speeds and more uniform application of torque save time of maneuvering the auxiliaries and mean a "snappier" mill.
d. Ward-Leonard controlled auxiliaries may save one to two kilowatt hours per ton, since there are negligible resistor losses. On a mill producing 600,000 tons a year, this means a considerable saving in dollars.

In the initial stages of applying these Ward-Leonard controlled auxiliaries, it was argued that their added cost was unjustified. We do not believe there is a blooming mill superintendent or electrical maintenance man now using Ward-Leonard controlled auxiliaries who will not vigorously defend them against magnetically controlled or hydraulically controlled auxiliaries and who will not testify that the Ward-Leonard controlled auxiliaries are worth their extra cost many times over.

JAMES FARRINGTON: First, I want to congratulate Mr. Wright on his able presentation of this subject, and the Edgar Thomson officials on their foresight in going ahead and embodying so many new and novel features on a mill of this kind. They seem to have incorporated all the desirable features in the industry. How does timing of a mill with two motors compare with one motor? How does the overall efficiency per ton rolled compare on the two motors to one on a mill driven by a single motor?

In our mill, which was put in in 1928, we have one 1,650 hp. edging mill which is ample, if all things are equal and the superintendent gets the ingots he needs and the open hearth man produces them just right; but there are plenty of times they do not come right and you have to do the edging work. We have found our motor too small. By incorporating a high-speed screwdown that discrepancy can be taken care of.

We did not have Ward-Leonard control on our auxiliaries, but we have put them on others, even as low as galvanizing units which are 30 kw. motor generator sets. Since they were put on with Ward-Leonard the upkeep has been practically nil, and I can say that applying the Ward-Leonard control to auxiliary drives has certainly been a wonderful step forward. The screwdown is badly punished and this method of control has overcome that condition. There was a question in my mind as to how you were going to equalize your load on two motors to take care of the difference in time between the vertical and horizontal rolls, and the two schematic diagrams show that is amply taken care of.

J. I. KASPARI: I would like to ask why single armature motors were used rather than twin armature motors.

R. H. WRIGHT: Mr. Morgan's discussion gives an excellent picture of the fundamental engineering problems which are encountered in the design and construction of a large slabbing mill.

We are indebted to Mr. Ellis for his explanation of the special mechanical features of the mill and to Mr. Rhea for a description of the variable voltage auxiliary drives.

Mr. Farrington has asked how the rate of acceleration of a twin-motor drive compares with that of a single motor. They are the same except that the lower flywheel effect of twin-motor drive makes it reverse with less current. In the case of a universal mill with an edger motor having 3:1 speed range the maximum rate of acceleration is determined by the characteristics of the edger motor. A motor with a 3:1 speed range must be accelerated at a slower rate than a motor with a 2:1 range. Where motors of both speed ranges operate in parallel the acceleration of the entire mill must be held within the maximum limits permissible for the motor with the 3:1 range. Regarding the difference in overall energy consumption of a mill with twin-motor drive and a mill with conventional drive, we have no definite information. Some of the twin-motor drives show considerably lower input to the flywheel motor generator than for conventional drives. However, a fair comparison can be made only when the rolling work is the same for both types of drive.

Mr. Kaspari has asked why single armature motors were used in the twin-motor drive rather than double armature machines. This was done to secure greater simplicity and lower cost.

MODERN LUBRICATION of Existing Equipment

By F. J. THOMAS, *Lubrication Engineer*

REPUBLIC STEEL CORPORATION

CLEVELAND, OHIO

Presented before A. I. S. E. Annual Convention, Pittsburgh, Pennsylvania, September 26-29, 1939

▲ "EXISTING EQUIPMENT" is of course a very broad term which should be applied to all machinery now in use in our companies. Some of this is of recent design and manufacture, but a very large portion has been in existence for many years. All of it, nevertheless, requires some form of lubrication. Let us regard the term "modern lubrication" as synonymous with efficient lubrication, although in practice this is not necessarily true. Then we can say that all of our existing equipment should receive modern, or efficient lubrication if it is possible to supply it. In the following I hope, in a general way, to mention some of the methods by which inefficient lubrication can be improved with the aim of ultimately making it as efficient as possible.

Just what is meant by efficient lubrication? To me it means that method of maintaining a film of suitable lubricant between all wearing surfaces so that (1) no wear takes place; (2) friction between those surfaces is reduced to a very small amount of fluid friction within the lubricant itself; (3) labor required for lubrication is negligible; and (4) lubricant consumption approaches zero. These are "hard words" and many will feel that they are impossible of attainment. In most equipment now in use it is necessary to compromise with this ideal and try to come as close to perfection as our limitations of design and surroundings will permit. Occasionally, however, we are permitted to see units which do come very close to attaining perfection in efficient lubrication.

It must be emphasized that each one of the four items just mentioned should be carefully considered and a real effort put forth to attain each without slighting any other. For example, it is possible to imagine a group of bearings in a large mill which are supplied with oil of a suitable grade in the right quantity from a wholly automatic oil circulating system. Here wear can successfully be combated, friction kept low, and labor of application negligible. Suppose, however, that the factor of lubricant conservation has not been given sufficient attention and poor bearing seals allow much of the lubricant to escape to the sewer, even permitting the entrance of contaminating moisture and scale into the circulation system, from which elaborate purification equipment and its accompanying labor are required to eliminate it. We cannot say that this is modern or efficient lubrication. No one of the four points mentioned can be slighted.

As mentioned before, very efficiently lubricated units do exist. There is a recently constructed cold strip mill with several 4-high mills whose back-up rolls turn in oil-film bearings which are lubricated from a central oil circulating system. Another central oil circulating system serves the reduction gears, pinions and their bearings. Smaller oil circulating systems supply drive units of flying shears, levelers, slitters, etc. Two automatic greasing systems supply grease to work roll bearings and most of the other greasing points of the mill, aided by several small manually operated greasing systems and a small portable electric grease pump. Wear and friction are kept very low, labor required for lubrication is very small, and there is very low lubricant consumption. For instance, lubricant cost per net ton of strip has averaged below $.0050.

Nor are all the efficiently lubricated units ones that have just recently been built. There are steam driven blooming mills where old engines are maintained in excellent condition, and on which bearing replacements are not very frequent. Some of these old engines are lubricated with admirable efficiency and economy. I have one in mind, which, besides having a record of extremely low maintenance costs, has lubricant costs averaging below $.003 per ton of blooming mill product, which I regard as being an extremely low figure.

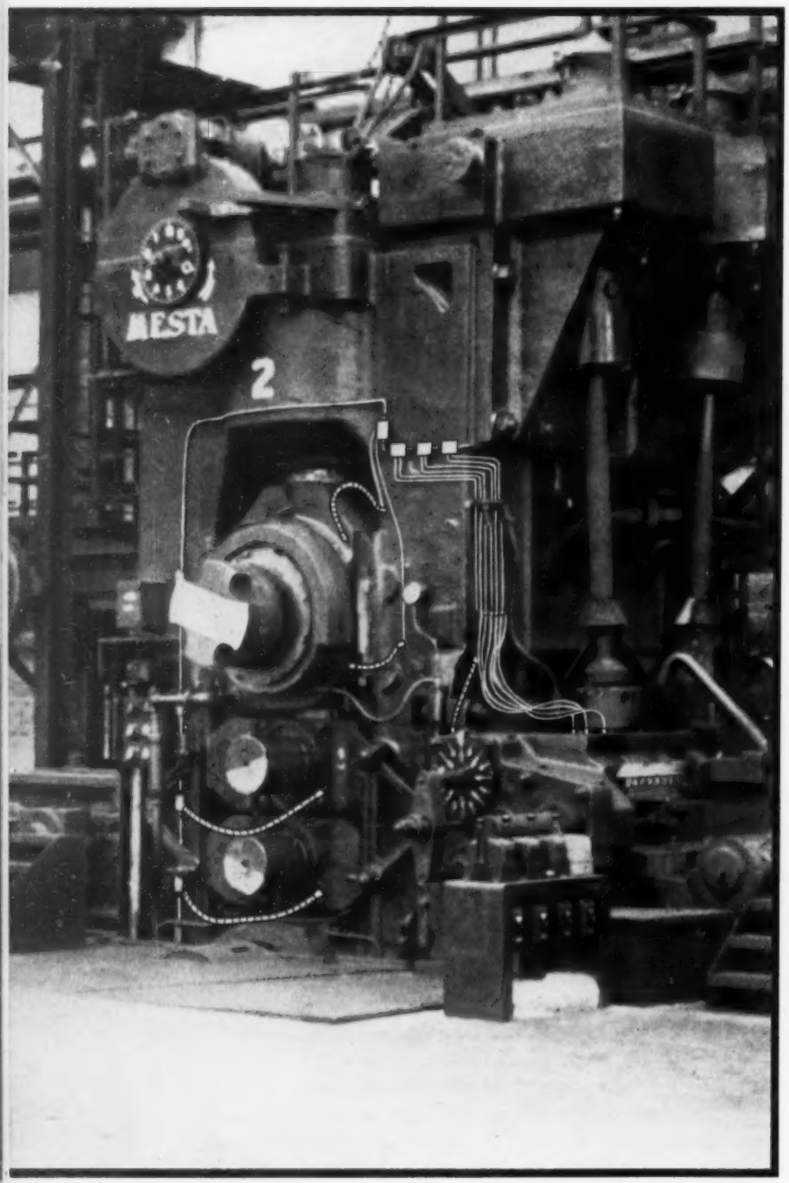
There are, however, many real obstacles in obtaining efficient lubrication on much of our equipment. Age is one. There are many efficient producing units in operation today, and some not so efficient, which have been in operation for many years. Many have been modernized from time to time, to permit higher rates of production. In these units many of the older and less efficient methods of lubrication still are maintained and the

earlier designs of bearings and gears are not easily adaptable to more efficient and economical lubrication methods. Frequently, maintenance costs are high due to these conditions.

But age is not the only obstacle. In their zeal to create newer equipment to perform hitherto impossible tasks, preoccupation with the main aim sometimes leads equipment builders to neglect improvements in bearing and gear design and in the methods for lubricating these. Thus it is that new and otherwise efficient equipment can frequently be very lame in design for lubrication. This is mentioned despite the fact that many equipment builders are very alert to provide easily and efficiently lubricated machines.

It is never easy to overcome the obstacle of poor design. Sometimes it is very difficult and very expensive. There are many ways in which improvements can be made, and some of these are not expensive, but neither do they bring as large returns. Naturally, no change should be made where no return will be realized. But if any of the four points mentioned previously are more nearly realized, some return is bound to be shown and some material benefit will result. Therefore it is necessary to study and determine one method which will give the best improvement for the amount of money available. The problem is one of engineering and economics combined.

Due consideration given to lubrication requirements in the design of mill equipment will prevent future trouble and inefficiency.



It is interesting to note how the various better known methods of lubrication may be applied to a simple 360 degree plain bearing consisting of a pedestal, cap and bushing of babbitt or bronze and in which a journal revolves. Let us visualize this bearing as having been designed many years ago, with a hole through the cap and upper half of the bushing to permit oil to be applied directly to the journal to reduce the friction as it revolves. Many are still being designed today in this way. The classic way to lubricate this bearing is to periodically pour a suitable grade of oil from an oil can through the hole on to the journal. For a moment we have the efficient condition known as flood lubrication. Friction is at a minimum, a generous film of oil supports the journal, no wear can take place. Gradually, however, the oil escapes from the bearing ends and goes to the floor and eventually, if a channel is available, to the sewer. If the pressure or the speed are not too great, it is possible that a very thin film will remain for a long time, supplying what is sometimes referred to as "thin-film or boundary" lubrication. Wear may be retarded for a long time and friction, while higher than with the complete film, will not be great enough to overheat the bearing. Eventually dirt will enter the hole and get into the bushing and wear may be accelerated. If the bearing is subjected to heavier service, it must be oiled with increasing frequency. Both labor and oil consumption are high for this type of bearing.

One of the first improvements was to put an oil cup with a drip feed on the top of the cap. The oil dripping from the cup can be adjusted to fall at such a rate that some oil film will always be maintained between journal and bearing. The cup may require filling only once every four to eight hours, which requires less labor and provides a fairly positive oil supply whether the journal is revolving or not. The oil continues to go from the bearing to the floor or the sewer.

Probably simpler than the above is the bearing cap with a recess in which wool waste can be packed or just a can containing wool waste where the oil cup just mentioned woul normally be. The wool waste is periodically saturated with oil, and this oil drips through a hole onto the shaft. In some cases the recess is designed to hold oil while strands of the wool waste wick feed it into a bossed hole and thence to the shaft. Application of oil can be made infrequently and quickly, but the rate of feed to the shaft must vary considerably with the degree of saturation of the waste and, to be safe, oil must be wastefully applied. Oil is lost, as before, after one trip through the bearing.

Oil cups which are thermostatic in their operation are sometimes used on lightly loaded shafts. No oil reaches the bearing until a rise in its temperature occurs. This rise causes a drop or two of oil to be forced down on to the journal and if the temperature rise is checked, no

more oil is fed. This type of cup can be very economically used on certain types of bearings. Various types of bottle oilers, functioning by vibration or temperature are available for use as oil cups.

All of the arrangements noted so far have the disadvantage of continuous oil loss. This need not always be necessary. I have seen numerous instances where oil catching pans have been attached to the ends of such bearings, with drainage pipes to a common sump so that most of the oil was caught and used over again. This requires more attention and labor than to allow the oil to be lost, but is usually worth while, despite the probability of contamination by dirt.

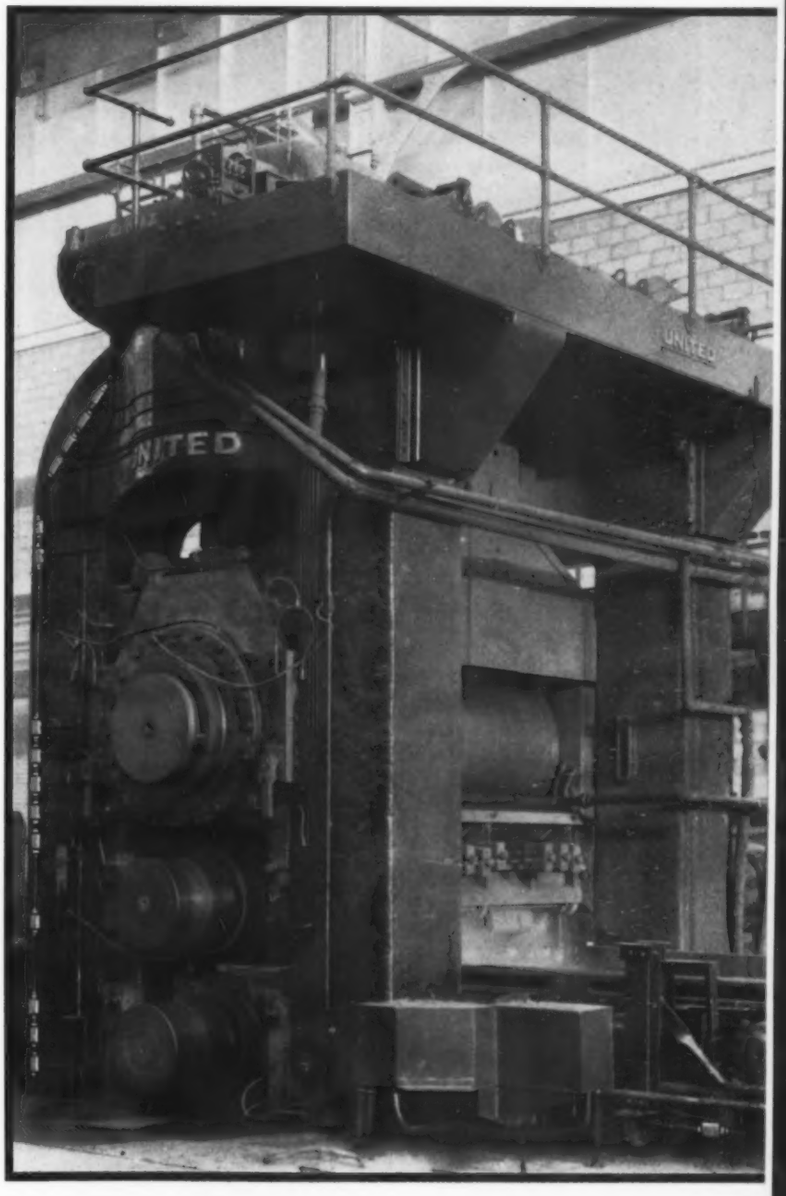
One of the earlier and still efficient methods of providing more positive lubrication to the plain bearing is the forced feed oil pump. In addition to being indispensible for steam cylinder and air compressor lubrication, this type of pump, driven from a rotating shaft by various means or independently with its own small electric motor, can provide accurately measured and timed amounts of oil to numerous bearings. Installation may be such that oil is supplied to bearings only when equipment is in operation, and this will be very positive. As previously mentioned, lubricant supply can be very accurately regulated. Labor required is only that of filling the oil reservoir when necessary. Disadvantages are the necessity or a separate oil line to each bearing from one central point, and the loss of oil except when efficient oil catchers are part of the bearings and these are drained to a common sump for further use. There is also the question of expense involved to be spread over a limited number of bearings.

In one blooming mill the pinion bearings were lubricated with a certain type of cylinder oil by means of gravity feed from home made wool waste packed oil cups. At an expense of around $150 a small motor-driven forced feed oil pump was installed to replace the oil cups. The pump motor was tied in electrically with main drive motor circuit, to run only when the main circuit is energized. Lubricant consumption alone was thus reduced enough over a year's period to pay for cost of installation, and bearing life has been lengthened about 70 per cent.

Now let us consider a different method. In a steam driven bar mill two bearings supporting a large belt driven pulley driving a train of roll stands were located at such a distance from the engine that they were not oiled from its oil circulating system. Drip feed oil cups were used on each bearing, and were watched closely because of the bearings' importance in the general scheme of things. Considerable amounts of oil were consumed by these two bearings. One day the millwright foreman got his hands on a small coolant circulating pump salvaged from an obsolete machine tool. Attaching homemade but efficient oil catching pans to each end of the two bearings, he ran drain pipes from them to a small sump tank. Above the bearings a ten gallon cylindrical oil container was placed. The pump was located near the rotating shaft and driven from it by means of a small belt and pulley, taking suction from the sump and discharging into the overhead container, which was also fitted with an overflow pipe back to the sump. From a point near the bottom of the overhead container a pipe carried oil to the bearings through sight feed fittings. When the shaft turned at normal speed the pump discharged more oil to the overhead container than was fed to the bearings and the excess overflowed back to the sump. Practically all the oil fed to the bearings was caught and also returned to the sump. Thus, at very small cost, a continuous film of oil was supplied to two important bearings, eliminating oil loss and the possibility of a bearing running without lubricant for a period because of a slip-up in keeping an oil cup filled.

This rather detailed description of a mill mechanic's ingenuity also describes most of the main items in that old but very reliable system of furnishing oil lubrication to large groups of bearings and wearing surfaces,—that is, the gravity type of oil circulating system. To the sump tank, the pumping unit, the gravity tank, sight feed fittings and piping, may be added such items as settling tanks or compartments, filter bags or screens,

Lubrication systems should be installed so as to be accessible for inspection, protected from damage, and adequate for the purpose they serve.



pressure filters, temperature regulators and heating equipment, float switches, centrifuges for water and dirt removal, warning signals and the like. But the principle of oil recovery and recirculation as embodied in the gravity type of oil system has for many years been an exceptionally efficient method of supplying lubricating oil to bearings, particularly when properly supervised and maintained.

Very similar to the gravity type of oil circulating system is the pressure type, in which oil is pumped directly to the points to be lubricated at a pressure maintained by pressure regulating valves usually operated in connection with a pressure tank. This tank acts either as an accumulator or just as a pressure chamber, depending on whether the pumps are run steadily or on an off and on cycle. In any case, the gravity tank is eliminated and on many small systems the pressure tank is also eliminated, its function being performed by the pressure relief valve which maintains a steady line pressure.

The pressure system has the advantage of direct pressure to each sight feed or sight flow fitting at bearings or spray piping. Without the necessity of running piping to an elevated tank it is easier to protect it and keep it warm in cold weather. There is only one tank to heat instead of two. Pressures are required today over longer distances, and these sustained pressures are more easily supplied by the pressure type of system.

With any kind of oil circulation system there are several essential points which, if followed, will assure simple, efficient and satisfactory lubrication.

1. Accessibility of piping for inspection and repair.
2. Protection of piping from damage.
3. Precaution when installing piping to prevent future leakage.
4. Design of bearings should be checked to see that all possibility of lubricant leakage from, or contamination entry into them is eliminated through proper sealing, drainage, slingers, baffles or packing. In other words, proper design should be insisted upon before approval of machinery drawings.
5. Sufficiently large pipe sizes, particularly drain lines, should be specified.

There are two types of plain bearings which deserve particular mention. One is the ring-oiled bearing, which is used on so much of our equipment. Each one of these is really a little circulation system of its own; the reservoir is the sump and the rings the pumping unit. In large motor rooms and on large, important units, these bearings are sometimes refilled continuously from separate oil circulating systems. Whether these separate systems are necessary or not is sometimes a matter of argument. When located in clean, well lighted and easily accessible surroundings the oil level indicators usually provided are suitable. But under the usual steel plant operating conditions, the ring-oiled bearing should have the protection of a constant-level, visual supply type of oiling device. These can prevent the carrying of too high an oil level, which promotes waste; they also provide an added factor of safety for the bearing. For example, the use of these devices on the pumps and motors of an isolated pump house greatly reduced the amount of time consumed by maintenance personnel in frequent inspection trips to see that all was well with the bearings.

It is particularly important to seal and protect ring-oiled bearings against leakage and contamination because they are so often used where this is very essential —electrical units, water pumps, blowers, etc. Where fans or blowers are mounted on ring-oiled bearings, protection against sucking of oil out of bearings by air currents should be provided.

Another type of plain bearing is the track wheel brass which is with us so abundantly on various types of rolling stock and most of our overhead cranes, charging machines, etc. The standard method of keeping this bearing lubricated has been the packing of oil soaked wool waste in the journal box, this waste being in direct contact with the journal. This has never been an entirely satisfactory method of lubrication. Frequent attention and expert repacking are desirable, but frequent injections of oil are the usual rule. If not disturbed occasionally the waste becomes soggy and drops away from the journal. At one time the use of a heavy grease supported by a steel plate and spring, or counterweight was thought to be a better method, but proved far from satisfactory and has generally been abandoned although this principle is still applied on many locomotive driving boxes. There are also the prepared wool yarn and hair lubricants with soap thickened oils or grease mixed with them, which have given somewhat satisfactory service in many places, despite their rather high cost. One of the most efficient methods of keeping this type of bearing supplied with a satisfactory oil film is the use of a tubular felt pad, held against the journal by light spring tension. Where suitable oils are used to saturate the felt, some having special adhesive properties, very good results are obtained with very little attention. In one plant a test was run with these on a blast furnace ladle car, a dump car, a coke rack and a locomotive tender. They were kept in use on each unit for a year's time, the report stating that they were "perfectly satisfactory and required no attention whatever."

Consideration of the oil lubricated plain bearing is not complete unless oil grooves are mentioned. These of course should be kept to a minimum and should never be permitted to enter the load carrying sectors of a bearing, where their presence may permit the destruction or reduce the efficiency of an oil film. Recently an electrical superintendent told me of some motor generator sets which were very important to the uninterrupted operation of this plant. The bearings of these units had been running warm enough to keep him just a little bit uneasy. The oil in use was the lightest grade he dared use. The bearings were of the ring-oiled type and were pretty thoroughly grooved in the bottom half, X-fashion. A spare set of shells was on hand and he had these babbitted without any grooves in the bottom half, just relieved a bit at the joint to allow the formation of an oil film. When these were installed in one of the machines the bearing temperatures ran from 10 to 15 degrees lower than previously.

Some type of grease has been used probably longer than oil for lubricating bearings. Open type plain bearings of which the older roll neck bearings are an example still use greases of one description or another. Solid greases of varying consistencies, soluble greases which

are gradually washed through bearings by streams of water, both are in present day use. Neither may be regarded efficient lubricants, but are used to combat poor bearing design. Consumption, friction and bearing wear are usually substantial. Newer types of bearings with more efficient methods of lubrication are gradually supplanting this older type. The use of more fluid greases, supplied by efficient greasing systems, can greatly increase the efficiency of the open type of roll neck bearing particularly in the larger, slower moving mills.

In direct comparison with the original oil lubricated plain bearing fed with an oil can is the similar plain bearing with a grease reservoir in the cap where soft grease can be packed. A cover can be supplied to keep the grease clean, although this is naturally something of a refinement. Heat generated by the bearing causes the grease to flow on to the journal in sufficient quantity to provide adequate lubrication and this grease can be replaced periodically by adding more with a paddle from a grease bucket. It is probably not necessary to point out that such methods, though inefficient, still exist. Sometimes copper rods are used to conduct heat from journal to grease.

To many plain bearings are attached grease cups with a threaded cover which, as it is screwed down, forces grease into the bearing. One filling may last for some time. There is one like that on the water pump bearing of my car and there are still numbers of them around steel plants, some on coke and coal conveyor bearings. There used to be many on overhead cranes. They are messy to fill, dirt can easily enter with the grease, threads were easy to get crossed and filling any number of them requires considerable time.

On overhead cranes, as in many other units, the grease cup has been gradually replaced by the pressure gun fitting and today most grease lubricated bearings have their grease forced into them through one of the various types of grease fittings by a hand operated grease gun. These guns are not easy to fill ordinarily and can easily be damaged or temporarily disabled by the entry of dirt, lint or pieces of wood with the grease. The best, easiest and quickest way to fill these guns is directly from the grease drum through a hand or power operated transfer pump. If a man is to grease a number of bearings by hand and more grease will be required than one gun will hold, several guns can be filled at one time and taken along. This is, of course, for inaccessible places where larger hand or power operated guns cannot be used.

The next step from the hand operated grease gun is the portable power (air or electric) operated grease pump. This can be a very efficient tool for greasing a large number of bearings in a very short time. One plant reported that on an open hearth ladle crane "previously equipped with hand screw grease cups, the use of grease fittings with the new electric grease gun made it possible to cover all the crane during limited greasing periods where previously this was impossible." On a sheet mill normalizing furnace, hand grease packing of the bearings of the slow turning but extremely hot rolls was a long and tedious job. The use of a small electric driven grease pump, plus suitable distributing piping, flexible grease hose with control valve and nozzle and grease fittings, cut greasing time and labor to one fifth of that previously required. Reduced lubricant consumption also resulted, amounting in a year's time to 60 per cent of the amount spent for the new method of applying the lubricant. Where many points are to be greased by hand, the portable power operated grease gun is usually the right tool to use.

Sometimes it is not possible to use a portable type of grease pump. A stationary pump often may be used to advantage in such a case with piping to various outlets conveniently located where a flexible grease hose and nozzle may be attached to grease all points within a certain radius. The normalizing furnace just mentioned was such a case. There are available for this service several types of air, electric or electric-hydraulic barrel pumps, able to supply quantities of grease at high pressures. These are very good in that they can be placed in and over the drum of grease as it is placed in use. The problem of grease transfer is eliminated, possibility of contamination is very remote, and it is a handy arrangement all around. Such pumps can and often do act as main pumping units for various types of pressure greasing systems.

The spring compression type of grease cup, filled through a standard pressure gun fitting, is frequently used on bearings where a small but fairly constant flow of grease is required. It is not easy to keep in adjustment, grease flow varying under varying temperature conditions, and its expense precludes any really wide usage. There are places, however, where conditions warrant its use.

Very similar to the forced feed oil pump previously mentioned is the forced feed grease pump. This is used in exactly the same way, driven by belt, chain or connecting rod, or by its own electric motor through a small speed reducer. Although limited to a certain number of outlets, a well known type of divisional feeder valve may be used on each outlet to multiply the number of bearings served from such a pump to a very respectable figure. Where bearings to be greased are located in a small area these forced feed grease pumps make very inexpensive automatic greasing systems. In one blooming mill such a pump is used to grease a number of points on the bloom shear, and four remaining outlets are multiplied by divisional feeders to take care of sixteen roll bearings on the table leading into the shear. In another blooming mill such a pump greases the pinion bearings and, through divisional feeders, all of the manipulator bearings as well. These small but efficient pumps may be found greasing such individual units as blast furnace skip hoist drive bearings, large mill pinion bearings, points on shears and slitters; medium sized roll neck bearings on individual stands; screwdown bearings, nuts, screws, square shafts and slides on blooming mills; pipe straighteners and other pieces of equipment, with very good results.

For many years it has been possible to grease a large number of bearings from a central pumping unit through a simple system of supply piping and ingeniously devised valves. This was termed a one shot system, since each valve delivered its quota of grease once each cycle of operation and then was through until the cycle was repeated. This term still describes practically all of our well known automatic or semi-automatic pressure greasing systems of today. The smaller and simpler of these systems employ a hand operated grease pump which

builds up grease pressure to operate the grease measuring valves which are located at varying distances from the pump and are usually close to the bearings to be served. In some cases the valves can be regulated to supply varying amounts of grease. In others different valves of fixed capacities must be used. In some, the valves are vulnerable to water, dirt and scale which may not affect other types. Some require higher pressures to operate than others. Some require more piping than others. These differences make very good selling points for one against another. The satisfying fact is that you can always find one to do the job you have in mind, and it need not necessarily be the same one each time. Instead of using hand operated pumps, power operated pumps may be used to push grease longer distances, supplying more and more points. More than one circuit of bearings may be greased at different intervals from such a pump. A circuit of bearings may be greased automatically at timed intervals. Other circuits off the same pump may receive grease at varying intervals through push button and control valve operation. With modern control equipment and power operated greasing systems almost any combination of greasing methods may be worked out. The value of such systems lies in their ability to supply a predetermined quantity of grease to a large number of points almost simultaneously. Labor saving, grease saving and, if the system is well maintained, certainty of lubricant supply with resulting long bearing life may all be obtained through the use of one of these systems in the right place.

These systems naturally are expensive to purchase and install and should be used only where justified. In the modern mills provision is made for such methods of lubrication because of the large numbers of bearings and their relative importance. Everything must flow swiftly and smoothly. Labor, for greasing or for any other purpose, must be kept at a minimum. Large amounts of grease are expensive and consumption is not difficult to control where efficient systems are used. So, despite their expense these systems are being used on the newer mills. Naturally, the expense involved varies greatly with the amount of work to be done. In one blooming mill which had been in operation for many years the roll neck bearings were hand packed with solid grease, slides were painted with heavy oil, screws were fed with oil and the table roll and lineshaft bearings from the soaking pits to the first shear were fed a mixture of grease and oil periodically by hand. Several years ago an automatic system was installed for greasing the roll neck bearings alone. Later, additional valves and divisional feeders were used to grease the screws, slides and feed roll bearings automatically. Still later a separate system was developed from the main pump and, using a different type of valve, the table roll and lineshaft bearings of the mill approach table were equipped for periodic greasing. Finally, both reversing tables were equipped for semi-automatic greasing with separate circuits from the same main pump. Even the universal coupling slippers are now greased by hand using the pressure developed by this central grease pump. All of this work covered a period of about a year and one-half, being done in slack periods. Together with the installation of several forced feed grease pumps for pinion bearings, manipulators, crop and slab shears a total of less than $7,000 was spent in making these improvements. One other change was the installation of roller bearings in place of bronze bearings on the flywheel shaft of both electric driven shears, a change that proved very successful, incidentally.

What justification was there for spending this money? Prior to these changes the money spent for bearings and bearing materials for this mill had averaged around 4.2 cents per ton of product rolled. This, of course, did not include cost of labor involved in making bearing replacements. This figure now averages about 0.7 cents, or a reduction of 3½ cents per ton. The mill is capable of rolling 70,000 tons per month, but in any one 30,000 ton month there is still more than $1,000 difference in money spent for bearing and bearing materials now as compared with the former period. There is also a saving in lubricant consumption and labor of application. Figures seldom tell the whole story. The mechanical and mill men usually know the answer. Where carefully planned, installed and maintained you are almost certain to find that these systems are very popular with the men who have to operate and care for the equipment which is lubricated by such methods.

It would be wrong for me to give the impression, however, that the mere installation of a more efficient means of lubrication will correct mechanical deficiencies. Changes in design of bearings are often very important in permitting their more efficient lubrication. The increased use of ball and roller bearings as replacements for plain bearings cannot be too strongly advocated as a means of simplifying lubrication problems and reducing maintenance costs. These bearings are not difficult to seal reasonably well against contamination or leakage and when used on suitably enclosed gear or pinion units can satisfactorily be supplied with the same oil that lubricates the gear teeth. The use of the so-called "oil film" bearing in place of open type plain bearings on roll necks has been very successful to date, and it is difficult to guess just how widely this type of bearing will be used in the future. The use of fabric type bearings on roll necks has been frequently discussed in papers and need just be mentioned here as another possibility in improving bearing design.

The lubrication of gears and pinions in steel plants has not received, in my opinion, the study and discussion that its importance requires. In automotive work certain gear lubricant standards exist. In steel mills, the same gears doing the same work in different mills may be supplied with lubricants ranging from light engine oils to heavy tar-resembling compounds. Briefly, we have three main choices of methods of lubricating gears, in order of their importance:

1. Paint or coat the gear teeth periodically with some adhesive compound.
2. Allow teeth to dip in a bath of some more or less fluid lubricant.
3. Direct a flow of fluid gear lubricant onto the gear teeth, preferably at the meshing point.

In all three cases gears should be enclosed in as oil tight a case as is possible. The choice of any one of these three methods of lubricating gears is affected largely by existing conditions, and these may in some cases be such as to make the oldest method the most feasible.

In discussing modern lubrication practice some mention must be made of the remarkable progress made in

recent years by our lubricant suppliers. These companies have made available for our use a large variety of excellent and remarkably able lubricants at reasonable cost. There should be no difficulty in obtaining proper lubricants for any type of equipment, although we will always have differences of opinion among ourselves as to which types are most efficient.

The purpose of this paper has been to discuss the methods available for efficiently lubricating our existing equipment and to point out some of the advantages of making use of these methods. We have very efficient tools for applying lubricants and very efficient lubricants to be applied. We can make use of very efficient types of bearings and power transmission machinery so that lubrication is simplified. Sealing and enclosure of bearings and gears can be accomplished with some degree of efficiency. New equipment for producing steel can be designed for maximum lubrication efficiency if we insist upon it. Efficient lubrication can be furnished existing equipment where it is needed. It is to the interest of anyone in any way connected with the production of steel to do what he can to promote increased lubrication efficiency.

DISCUSSION

PRESENTED BY

T. R. MOXLEY, *General Master Mechanic*, Wheeling Steel Corporation, Steubenville, Ohio.

R. M. GORDON, *Manager*, Gordon Lubricators Division, Blaw-Knox Company, Pittsburgh, Pennsylvania.

F. L. GRAY, *Lubrication Engineer*, Carnegie-Illinois Steel Corporation, Gary, Indiana.

E. S. GLAUCH, *Mechanical Engineer*, Lubricants Department, Joseph Dixon Crucible Company, Jersey City, New Jersey.

S. A. NEWMAN, *Assistant Division Manager*, Gulf Oil Corporation, Pittsburgh, Pennsylvania.

W. H. MANDY, *Lubrication Engineer*, Texas Company, Birmingham, Alabama.

T. R. MOXLEY: It was interesting to note the progress that has been made in the lubrication of the older machinery, some of which I have been tangled up with for a long while. As this newer type of machinery is being supplied to us today our lubricating problems have been materially reduced. However, even so we still have some of those problems with us. As Mr. Thomas has stated in his paper about the electrician that was having trouble with the motor-generator set, I believe we have found in some cases that it has been necessary for us to try to figure some way whereby we can eliminate the troubles with newer equipment.

One of the things that has seemed to be overlooked to a certain extent is the application of the lubrication inside the bearing after it has been applied. Unless we get a uniform distribution of the lubrication inside of the bearing in such a manner that it can be distributed to portions of the journal which carry the load, then we have another job to do. We have had to do that in several cases and we have been successful to the point where the bearing temperature was entirely reduced, likewise the amount of oil supplied to the bearing was reduced.

One of the things that Mr. Thomas spoke of was the lubrication of journals on ladle cars and other rolling stock. The pad that he mentioned is held up there with a spring and has worked out very favorably for us on our iron ladles at our blast furnace. However, we were confronted with ingot car axle trouble. We have a narrow gauge ingot car at our plant, and as the weight of our moulds became greater, it was almost impossible to keep those small journals lubricated, the plain bearing type.

Therefore, we went in for rebuilding our ingot cars and building some new ones and with the aid of the manufacturers, we installed roller bearings on these journals and since that we have had absolutely no trouble whatever. Our bearing trouble is practically nil. Our lubricating costs have been materially reduced, and the same locomotive today can haul one and one-half to two times as many cars as before.

As Mr. Thomas has said, we shouldn't have any problem today that can not be solved from a standpoint of lubrication, as the progress that has been made by lubricating companies and by those companies who provide the equipment with which to supply this lubricant has materially reduced our problems so far as effecting proper lubrication.

All of us who are old enough, and I think we all are, used to consider the man with the oil can the oiler, and an oiler was looked upon as just another one of those fellows who poured oil into a bearing. We have found that taking a man of reasonable intelligence, and training him as to how the lubricant should be applied, has paid us more dividends than any other thing we have in our plant so far as the application of lubricants is concerned.

When we first put in our automatic lubricating systems we didn't have what we have now. Better connections, improved hose, and similar items have been developed to meet the mounting requirements, and I want to give a lot of credit to the people who are manufacturing that equipment today, as it certainly got us out of a lot of trouble.

R. M. GORDON: I do not believe that simple confirmation constitutes a proper discussion for a technical paper. I think that any discussion should be critical at least to the extent that it evokes some differences of opinion that will result in general discussion. I know that my friend, Mr. Moxley, feels as I do in this respect, and from the fact that he could not find anything to criticize in the author's paper, I am sure that he must agree that Mr. Thomas has not left much room for controversial discussion. My remarks, therefore, must supplement the author's and they are directed along the line of application of lubricating equipment to existing equipment.

I believe we are all agreed that the work of a lubricating engineer consists first in selecting the proper lubricant for the job, and next in seeing that it is properly applied. Now in order to do that properly, he has to have a fair amount of mechanical ability, and in

almost all cases, has to know a good bit about the operating conditions to be encountered as well. Taken all in all, it is a pretty comprehensive job. I think in most cases, the lubricating engineer has been hampered during the last few years by his inability to get money to perform the various jobs which he would like to accomplish. In my talks with the various plant lubricating engineers, I found that all of them have many jobs which are being held up for lack of sanction of the necessary expenditure.

I believe that this attitude on the part of management is changing rapidly and, is apt to change even more rapidly in the next few months or years, if we continue to enjoy such a high rate of productivity, because after all, management usually listens when you talk tonnage, and in times of high percentage operation, lubrication means real money. In times of slack operation, it is not particularly expensive to stop a mill to grease it, but now when stopping means the piling up of orders, or in the case of a crane, the losing of so many lifts in the five or ten minutes allotted to greasing, time is of the essence, and each unnecessary delay causes a corresponding loss in tonnage.

I would like to point out that almost without exception, your old mills are amenable to modern lubrication, with little or no change from a mill design standpoint. Automatic lubricating systems are available that can be installed over a week-end without interfering with, or slowing up, production. Experience has shown that it is generally advisable to break the ordinary maintenance routine to the extent of making a lubricating system installation on some particular week-end. Such a procedure generally means that each succeeding week-end thereafter, there is more time available for other work than the changing of bearings or replacing of broken line shafts which formerly were a large part of each week-end job, and which were to a large extent at least, necessitated by poor lubrication.

One mill superintendent in this district has made the statement, and repeated it many times, that 80 per cent of all mechanical failures in his plant are due to faulty lubrication. You may not agree with the high figure of 80 per cent, but there is no question but that a lot of our mechanical failures could be eliminated by better lubrication.

I would like to mention another point that seems pertinent in the light of present day conditions. I know a lot of you are in the throes of trying to start mills that have lain idle for several years or more. A lot of these mills are going to be called on to roll sections and orders outside of the original scope of the mill. For example, sheet bar mills originally designed for 9 or 10 in. sheet bar will be called upon to roll perhaps 14 in. bar. This practice of course will result in badly overloaded mills, and excessive wear and more frequent replacements from a standpoint of bearings can be expected.

In mills of this type, the installation of an automatic grease lubricating system will greatly reduce the friction load and greatly prolong the life of the bearings. I know of one blooming mill which is only a few miles from the one Mr. Thomas described in his paper, where a badly overloaded condition existed. In this instance, the installation of a grease system not only eliminated the overloaded condition, but enabled the operators to increase their tonnage by about 10 per cent. This increased tonnage of course means much more than any dollar saving that resulted from bearing labor or power saving. As a matter of record, however, an actual power saving of about 4 kwh. per ton resulted from the installation. This saving alone paid for the complete investment in approximately two months' time.

While 600 per cent savings like that described are perhaps not the rule, I am safe in saying that installing lubricating systems on old type mills will generally return you 300 or 400 per cent on the investment.

I know you will all agree that 300 or 400 per cent is at least a fair return on your money and I trust that Mr. Thomas' paper and these subsequent discussions will encourage you to consider carefully the advisability of proper lubrication for your existing equipment.

F. L. GRAY: I think Mr. Gordon was a little high when he said 80 per cent of our delays were due to faulty lubrication. In looking over our delay sheets in the years past, you will not find a mill delay charged against lubrication. However, today, people are more conscious of lubrication, and from the reports I get it looks like 99 per cent, including the cobbles, are charged against faulty lubrication.

E. S. GLAUCH: Plant lubrication engineers and officials are asking more than ever from grease today and I believe that all grease and lubricants manufacturers are trying to give the operators what they want and their equipment requires. Sometimes we, in the lubricants manufacturing field, have a hard time finding out just what is desired. If the problem is presented to the various manufacturers they will do their best to try to give the operator a lubricant that will carry the load and do the job at higher speeds and under heavier load conditions that apply today and that will apply in the future. Now, of course, my particular concern specializes more or less on specialty production, that is, graphite greases and lubricants. A great many of the other grease manufacturers use similar types of materials in the production of their lubricants. There are, of course, certain jobs where that product, that is, the graphite lubricant, will do a better job than the plain lubricant. On other jobs it isn't desirable or necessary. A lubricant must be selected for the job and I believe since the various mills have had men that devote most or practically all of their time to lubrication that better results are being obtained.

The reason being that before the individual superintendents who were responsible for production would decide that a certain product was giving satisfactory results and they weren't interested or did not have the time to conduct tests on new lubricants. Today, however, everybody is looking for greater efficiency and lower production costs which in turn means that they desire improved lubrication.

As I see it, the combination of the mill lubrication engineer, the system manufacturer, and the lubricants manufacturer have done a pretty fair job in accomplishing these results. Of course, there is always room for improvement and I don't know that I can add a great deal more at this time, excepting to say, as I said before, that Mr. Thomas did a pretty thorough job. Also, as Mr. Gordon said, with the information in the paper and

that which has been added by previous discussers, there isn't a great deal left for anyone else to say.

I will say, however, for all the grease manufacturers that if the mill men and lubrication engineers will present their problems to us, we will all try to help them out and give them better and improved lubricants than those they have been obtaining in the past.

S. A. NEWMAN: I feel that Mr. Thomas has handled his subject of modern lubrication of existing equipment in a very clear and precise manner. His emphasis on method of application is of course proper and correct. It is our experience that at least 60 per cent of the lubrication troubles experienced with existing equipment can be corrected by improvements in application methods. Some of the best work our field men have done in recent years has been their cooperative efforts with plant lubrication engineers and others responsible for maintenance and lubrication of equipment.

Particularly during recent years when business conditions have dictated a rigid policy of economy and efficiency in plant operation, the more progressive companies have made greater use of the cooperative service leading oil companies are prepared to render in assisting them to secure greater lubrication efficiency and the consequent reduction of maintenance cost. The personnel of our organization, and the same is true in the entire industry, has been built up during the past ten years to a point where the companies are represented in the field by men who are technically educated and schooled in the application and use of lubricants. They are fully capable of consulting with plant engineers regarding their lubrication problems and recommending the use of properly selected lubricants and efficient methods of application.

Mr. Thomas has said that there will always be differences of opinion among operators as to types of lubricants which are most efficient. It is likewise a fact that there are differences of opinion among all technologists who are constantly testing systems and devices as well as lubricants.

With the increased precision of modern machinery, the need for better and more suitable lubricants is apparent, and you will be interested to know that our research people have determined that very slight differences in oil quality may have a great influence on the efficient operation of many modern types of equipment.

The effect of various metals on oil is recognized, for which reason the selection of crude and the manufacture of the finished lubricant is of the highest importance. As an illustration, copper and copper alloys are particularly objectionable in circulating systems.

Greater precision, higher speeds, greater pressures, and greater extremes in operating temperatures have made the proper selection, as well as the application of lubricants increasingly important in the efficient operation of equipment in use today.

The petroleum industry recognized the necessity for the development of efficient lubrication systems to perhaps as great an extent as does the operator, and in connection with the development of the best and most economical lubricant have endeavored to duplicate operating conditions in the laboratory. For instance, in developing journal oils for railroad use, the oil is worked out under actual operating conditions on journals having all of the speed, motion, and weight that would be encountered in actual railroad service. The same is true of the development of steel mill lubricants, and this work, in addition to our daily experience in the steel mills, is going far toward the solution of the serious problems outlined. This endeavor on the part of the industry in conjunction with the advice of able lubricating men will eventually result in economy of operation and greater efficiency.

W. H. MANDY: I would like to stress the point made by Mr. Thomas regarding the maintenance of oil circulating and grease systems. It has been said that no oil or grease system is any better than the maintenance given it and I think this is true. It isn't fair to the manufacturers of these systems to expect them to perform satisfactorily month after month unless periodic inspections are made to be sure that there are no leaks in the lines and at the measuring valves, and pump. The pumps and valves should be kept as clean as possible and the oil and grease lines should be painted frequently especially where they are exposed to moisture and acid fumes. Grease lines which have been mashed together or are badly corroded should be replaced immediately. The points of lubrication should be checked to be sure that the proper amount of lubricant is being supplied; this is particularly important with new installations because it is often necessary to adjust the measuring valve or replace it with a different size valve to obtain the proper amount of lubricant.

Some plants appreciate the importance of proper maintenance on these systems enough to assign a man to them. He is acquainted with every detail of the system and is supplied with proper tools to make any necessary adjustments or repairs. It is to the interest of the lubricant manufacturers that these systems be maintained and operated properly because if a bearing fails, even though due to insufficient lubricant, the quality of the lubricant may be questioned.

Observations on the HEATING of STEEL from the Metallurgial Standpoint

▲ PREVIOUS papers presented before this society have covered quite adequately the factors involved in the successful heating of steel. The object of this paper is to illustrate certain of these fundamental principles from the standpoint of ingot heating and to discuss some of the other problems, such as surface defects, which are closely allied to them. Surface quality of the rolled bloom is the main criterion used in determining whether the heating has been successful. However, the heating is not entirely responsible for the poor surface quality which sometimes occurs. In this paper we will attempt to present some of the other causes of surface defects and thus indirectly exemplify the true importance of heating practice.

HEATING TEMPERATURES OF ALLOY STEELS

To the uninitiated the correct heating temperatures of steels increase as the alloy content becomes greater. Allowing for the exceptions to be noted later, this is not correct. In general, regardless of the alloy content the correct heating temperatures in the soaking pits are a function of the carbon content, as in plain carbon steels. Usually, when an alloy steel does not follow the carbon-temperature curve, it is because of certain peculiar effects which the alloys have produced in the physical makeup of the steel, and not because it has greatly changed the incipient melting range of the steel.

FIGURE 1

FREEZING RANGES--DEGREES F.

Iron-Carbon Diagram		Cooling Curve Determinations		
Per cent carbon	Freezing range	Freezing range	Type steel	Analysis
.15	2770–2720	2732–2645	4615	.15 C, 1.75 Ni, .25 Mo
.40	2740–2640	2685–2575	3140	.40 C, 1.25 Ni, .60 Cr
.50	2730–2600	2665–2565	6150	.50 C, 1.0 Cr, .18 V
.65	2710–2540	2620–2550	1065-R	.65 C, .25 Mo

The table in Figure 1 compares the freezing ranges of iron-carbon mixtures as taken from the iron-carbon diagram with freezing ranges of some grades of alloy steel. These latter ranges were determined by immersion of a platinum-platinum-rhodium couple in the molten steels. In these determinations the temperature dropped rapidly as compared to the slow rate upon which the iron-carbon diagram is based. In these cases it will be seen that the freezing ranges of the alloy steels decrease as the carbon contents increase and always are lower than the iron-carbon ranges.

Another indication of the predominance of the carbon content in determining the heating temperature may be seen in Figure 2. In the banded zone on this chart are plotted soaking pit draw temperatures of quite a variety of alloy steels. All the heats represented were products of a one-way fired pit, and for which the surface conditioning costs on the rolled blooms were at least as low as our plant averages for the individual types of steel. The following types of steel are included in this chart:

Plain carbon, nickel, nickel-molybdenum, chromium, nickel-chromium, manganese, nickel-molybdenum, chromium-molybdenum, chromium-vanadium, chromium-nickel-molybdenum, stainless types, and some corrosion and heating resisting steels which may contain in addition to the alloys mentioned above, tungsten, silicon, aluminum, columbium, etc.

In addition there are several additional types included which are worthy of further remarks. The 1.50 per cent carbon heats at the extreme right end of the chart are unusual because of the high carbon content and low rolling temperatures. These represent what we have

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Pittsburgh, Pennsylvania, Sept. 26-29, 1939

named graphitic steel, which in addition to the high carbon, may also contain .70 to .90 per cent silicon, with or without .20 to .30 per cent molybdenum.

The safe temperature range for these steels is quite narrow. They are very hard even at the correct temperature. If the temperature exceeds this range even a slight amount, the ingots pull apart in the mill. If rolling is attempted below the range, they are so hard that they will not go through the mill and may break the rolls. In preparing this steel for rolling it is extremely important that it reach the mill and be reduced without any loss of time. If an ingot is delayed even a minute longer than normal, it cannot be rolled. Also, when starting to draw the pit the temperature cannot be allowed to either drop off or increase between withdrawals.

At the upper end of the chart are several heats of regular 18–8 stainless steels. It can be seen that they fall above the band. But point A, which is considerably below the band, is a .08 per cent carbon, 18.0 per cent chromium, 11.0 per cent nickel stainless which also contains .87 per cent columbium. If this steel is rolled at the temperature employed for the 18–8 type, the ingots break apart, and examination discloses a marked columnar crystalline case, the failure occurring because of weakness at the boundaries of the long wire-like columnar crystals.

THERMAL CONDUCTIVITY

In heating alloy steels one of the most important factors involved is the thermal conductivity of the steel. In general, as the alloy content increases there is a decrease in the coefficient of thermal conductivity. This is shown in the following table of values taken from the International Critical Tables:

Nickel Steel		*Chrome Steel*	
Per cent nickel	*Conductivity*	*Per cent chromium*	*Conductivity*
0.....	.410	0.....	.418
5.....	.320	5.....	.305
10.....	.258	10.....	.218
20.....	.175	20.....	.179

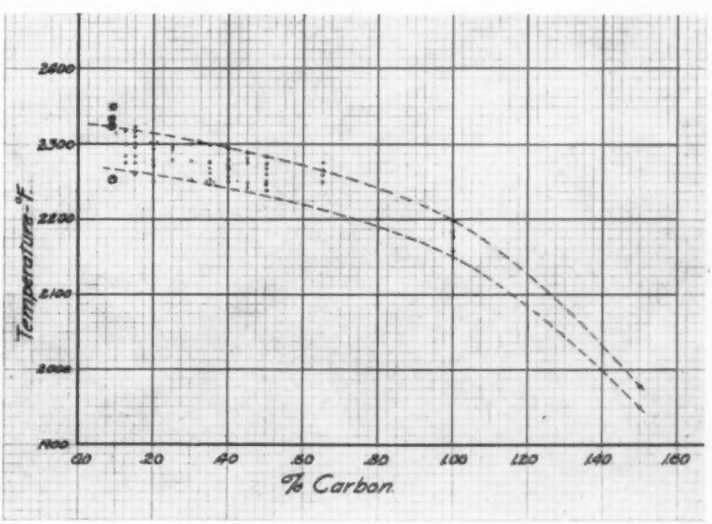
The unit of conductivity here is 1 watt per cm. per degree C.

From these data it is seen that the conductivity value changes greatly as alloy content increases. A decrease in conductivity has several effects on heating, one of which is sometimes overlooked. Naturally a steel of low conductivity will not absorb heat as fast as an ordinary steel so more heating time is required. But another effect is the change in the temperature differential between the inside and outside of the steel. This is illustrated by the curves in Figure 3. These curves are not intended to be truly representative of actual conditions but do illustrate what occurs. They were calculated from the Grober curves on the heating and cooling of solid bodies as recalculated and interpolated by H. Bachman.

The temperatures of the inside and outside of a 19 in. diameter cylinder (or ingot) were calculated for the following conditions. For purposes of illustration the ingot was assumed to be at a uniform temperature of 1700 degrees F., the furnace temperature at 2300 degrees F., the heat transfer coefficient equal to 30 Btu. per sq. ft., per hour, per degree F., and the coefficient of thermal conductivity equal to 40 Btu. per ft., per hour, per degree F. Values were obtained for 2, 3, 5 and 6 hours heating time and are shown as solid lines on the chart.

The second set of curves (dash lines) were for the

FIGURE 2



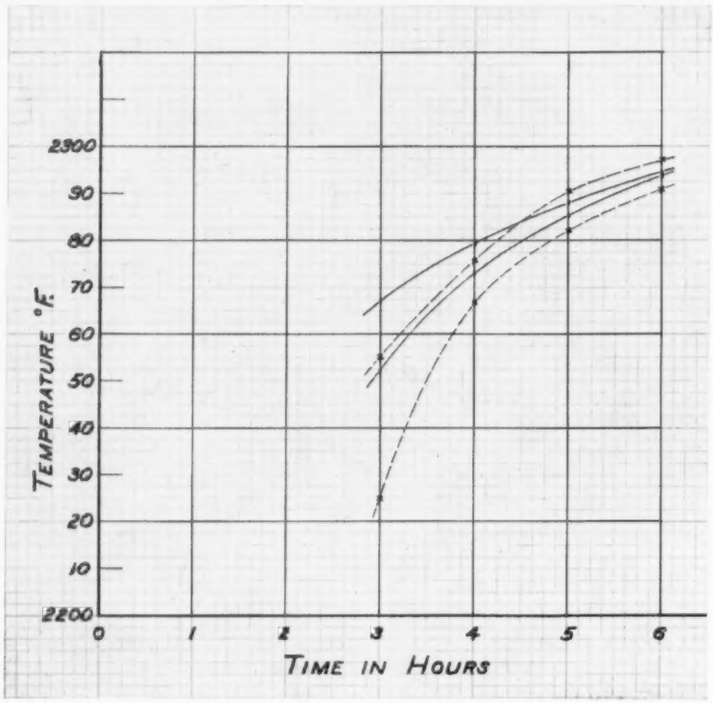
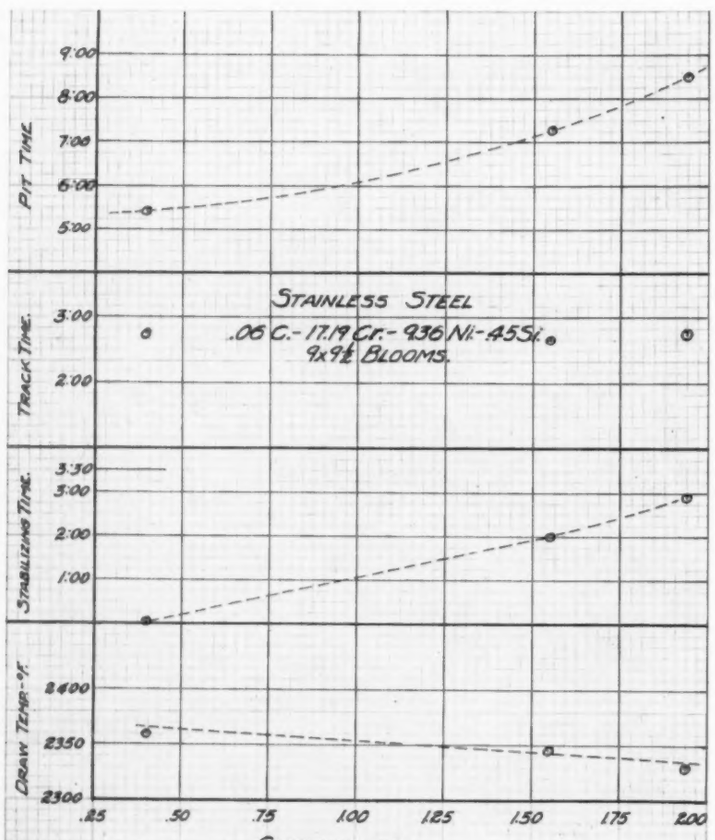


FIGURE 3

FIGURE 4



same conditions except that the conductivity factor was decreased to 30 Btu. These curves show the greater temperature differential produced by the lower conductivity value, and indicate that longer heating time is required. The differential may also produce injurious stresses in the steel. Also note that the surface temperature of the low conductivity steel increases at a more rapid rate than the high conductivity steel at the latter stages of heating.

At this time we would like to add that after these theoretical curves were calculated, further checking and study have indicated that the results obtained, at least for the conditions set up, do not agree too well with what we believe will actually occur. Conductivity values vary with temperature, and under actual heating conditions some of the other factors will not remain constant as assumed in the calculations. If we compare surface temperatures of two steels having conductivity values such that at any temperature the conductivity value of one is always lower than the other, then the surface temperature of the steel having the lower value always should be higher than that of the steel of higher conductivity value.

Under the conditions employed in the above example the results do not work out this way, and to date we have been unable to find a satisfactory explanation for this apparent discrepancy. Since the use of the Bachman curves can be of definite value in predicting and studying heating rates, it is to be hoped that a suitable explanation can be found.

The significance of these changes can be appreciated if we consider it as occurring under actual furnace conditions. Actually, the furnace temperature, or more correctly, the heat source, may not remain at 2300 degrees F. as assumed. If it does not, then it is apparent that the surface of the low conductivity steel is more susceptible to being overheated or burnt.

In furnaces where there is lack of close control this condition may account for much of the grief encountered in high alloy steels. The point of the illustration is that even if we attempt to reduce the rate of heating and fuel input, if we slip off the heating cycle the steel is apt to be injured.

TIME-TEMPERATURE CURVES

The accompanying series of charts are presented to illustrate the relationship between time, temperature and surface quality in the soaking pit operation, and further, to indicate that for a particular type of steel there is a range of time-temperature relationships which produce the best surface condition. Naturally, the condition of the steel as it reaches the pits has no small effect on surface quality, but except as otherwise noted the heats shown on these charts are ones in which furnace practice and pouring pit technique have been such as to produce satisfactory quality steel if processed properly in the pits.

All heats shown are the product of a soaking pit under complete automatic control and on which detailed and permanent records of the various items are available.

The following are explanations of the terms used on these charts. In all cases the abscissa is tons of steel

hand chipped per man hour and is indicative of the surface quality. Track time is the time from finish teeming of the last ingot of a heat to the finish of charging in the soaking pit. Pit time is the time from finish charge to start draw. Stabilizing time requires more detailed definition. In this pit when the temperature reaches the desired control point the fuel input rate automatically decreases until it reaches a certain minimum rate at which time the heat input is actually being used only to compensate for heat losses through the furnace structure and out of the stack. In this particular pit this fuel rate is from 1100 to 1300 cu. ft. per hr. of 1050 Btu. natural gas. Stabilizing time as used herein is the period from the time the fuel rate drops below 2000 cu. ft. per hr. to the time drawing was started.

Figure 4 includes three heats of 18–8 type stainless steel. They were all made in exactly the same manner, tapped at the same temperature and teemed at the same rate. There is only 5 minutes variation in track time. In all cases the pit temperature at start of charge was between 1910 and 1930 degrees F. Rate of fuel input varied slightly but all were started off at medium low rates which were increased slightly in steps as the temperature increased, but which never reached the higher rates normally employed on low alloy content steels. The heat at the left side of the graph had the poorest surface condition in that it required the most chipping. Note that it had no stabilizing time. It was heated to a higher temperature than the other heats but there was no indication that it was overheated or burnt. The other two heats were heated to a lower temperature but had long stabilizing times, indicating that they were thoroughly soaked. This chart brings out two important factors in the heating of this type of steel: (1) that even with the high alloy content extreme high temperatures are not necessary and (2) the beneficial effect of soaking time.

Figure 5 shows another type of alloy steel on which our first efforts at heating were not too successful. Note that the heats at 2250–2260 degrees F. did not produce a very satisfactory surface even though they all had a fair stabilizing time. Note also that at this temperature the surface improved with longer stabilizing time. The heat having the best surface was heated to 2300 degrees F. and had a long stabilizing time (this extra long time was due to a mill delay). The heat at the extreme left, having the poorest chipping, deserves an explanation. It had sufficient temperature and time but had a ladle skull and the ingots had a rough surface when charged into the pits. Evidently this poor surface cannot be blamed on the soaking pit.

Figure 6 shows a greater number of heats than the previous ones and while a line curve cannot be drawn the trends of the heating factors are quite clear. Again it is seen that as the temperatures increase and reach the range which their carbon content predicts, the surface quality improves. And it also improves as the stabilization time increases.

Figure 7 shows a group of S.A.E. 4140 type heats in which the stabilizing time appears to have a marked effect on the surface quality. Again it is noted that the skulled heat, even though it had ample time, produced poor surface, as did the heat which was charged cold and which had no stabilizing time.

Figure 8 shows a type of steel which is not difficult to

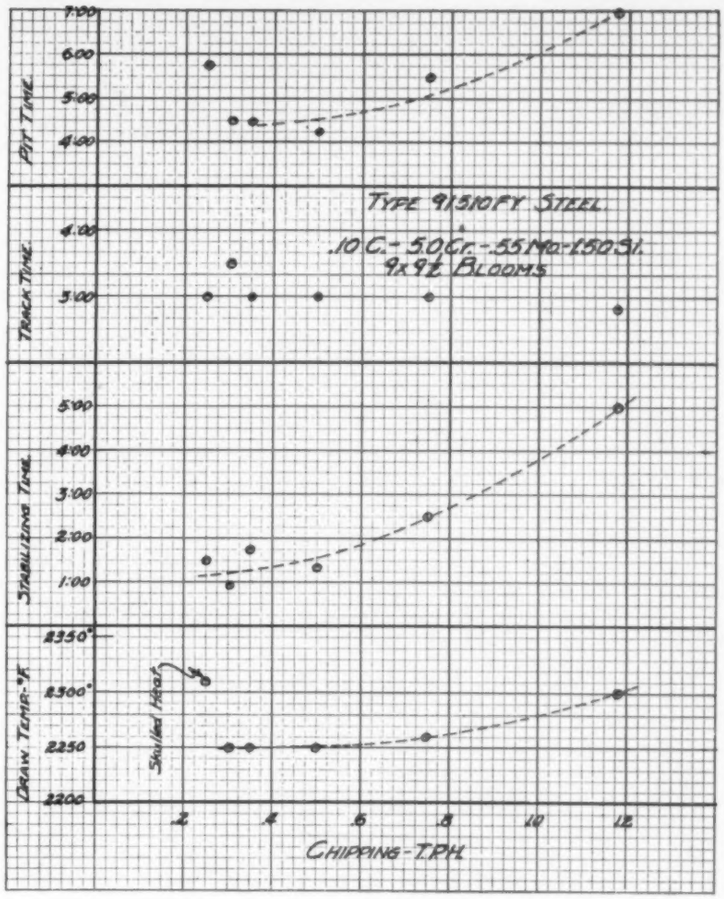
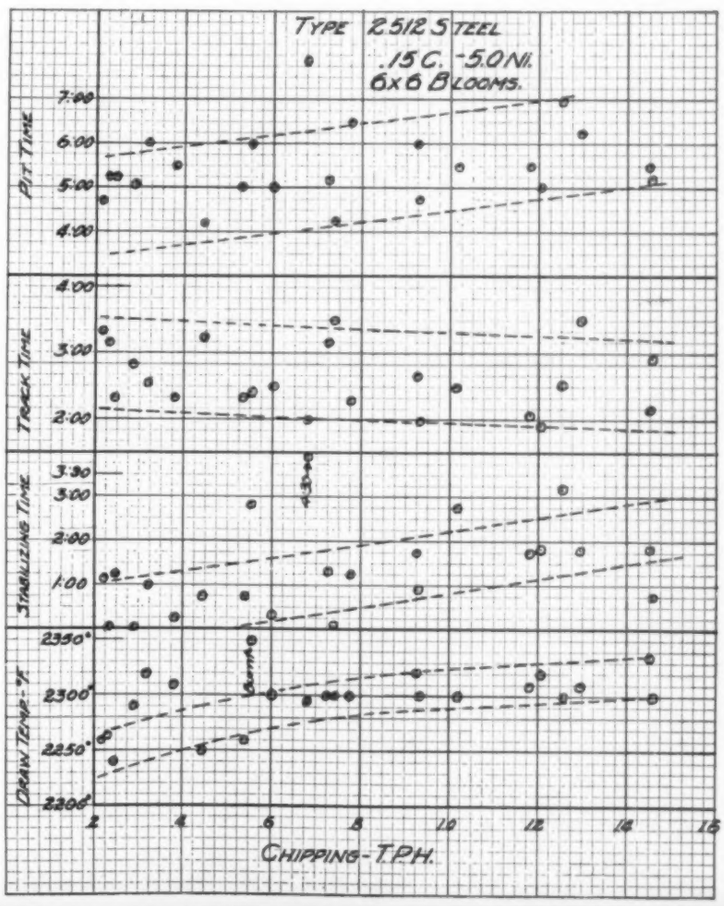


FIGURE 5

FIGURE 6



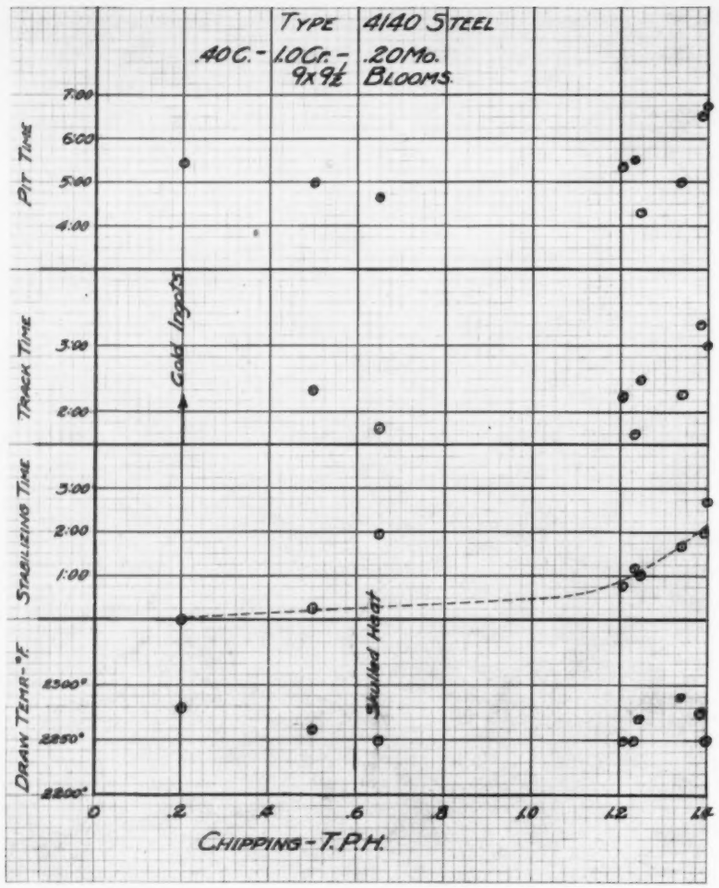
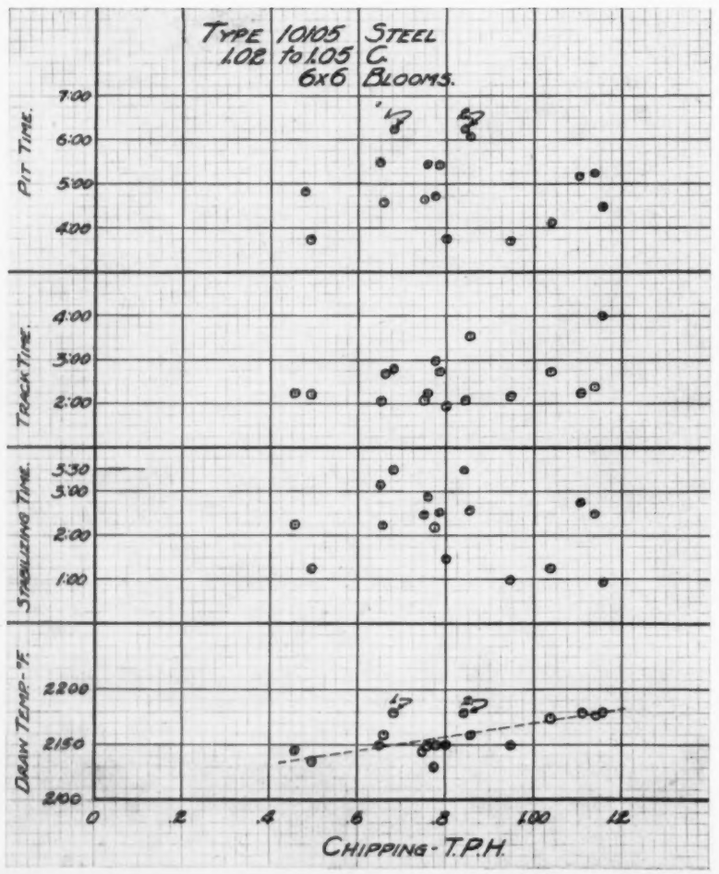


FIGURE 7

FIGURE 8



heat. The only trend indicated is that best surface is obtained with the higher temperatures. The principle types of defects found in this steel are seams and small scabs. We believe these seams are due to excessive amounts of scale which gets rolled into the blooms. It is interesting to note on this graph that heats marked 1 and 2, although carried to the preferred temperature, were in the pit the longest time. This checks with our belief that excessive scaling (in this case, produced by the long time) is detrimental. Evidently this type of steel should be heated rather rapidly to 2180 degrees F. given a 1 to 2 hr. stabilization and then drawn as soon as possible before excessive scaling develops.

SURFACE DEFECTS

Other factors in addition to the heating of steel which may affect the surface quality are the variables encountered in melting, pouring, and handling of the heat prior to delivery to the soaking pits. A knowledge of the effects of these items is of great importance to anyone who is responsible for surface quality and may save one from doing a lot of unnecessary work on heating practice.

The final analysis of the steel may affect its susceptibility to surface defects. Foreign elements such as Cu, Sn, As, Sb, etc. which contaminate the charge may produce red shortness. High sulphur produces red shortness but can be mitigated by proper balance with Mn and proper deoxidization practice. Analysis may also affect the ingot structure. Certain analyses tend to cause segregation during cooling and result in large columnar crystals which produce lines of weakness in the steel. An example of this is the stainless heat with .87 per cent columbium mentioned earlier in this paper.

The composition of the steel may be such that a two-phase structure is present at the heating temperature. Ordinarily austenite is the only phase present at rolling temperatures. Certain analyses high in Cr, Si, Al, etc. tend to promote the formation of ferrite and unless the composition is suitably balanced by adjustment of C, Ni and Mn, mixed phases may result. A structure which is entirely austenitic or ferritic will roll satisfactorily but the presence of mixed phases may cause difficulties. The state of deoxidization of the heat and the presence of gases may also affect surface characteristics.

Teeming rates and temperatures are very important in controlling skin thickness of ingots, cracks, scabs and other defects. An example indicating the importance of teeming rates is shown by Figure 9. In this experiment twelve heats of 52100 type steel were made in the same electric furnace using alternately 1½ in. and 1¼ in. diameter nozzles. All other conditions were maintained as similar as possible. The results show clearly that the heats having the faster pouring rate produced much better surface.

Other factors, such as mold design, mold temperatures, mold washes, and type of hot top affect the surface quality of the ingots. The time elapsing between teeming and moving the ingots also is of importance as is total track time.

After the steel is rolled the rate of cooling may affect surface conditioning costs. Cracks or bursts may develop in some types of steel if improperly cooled, or the

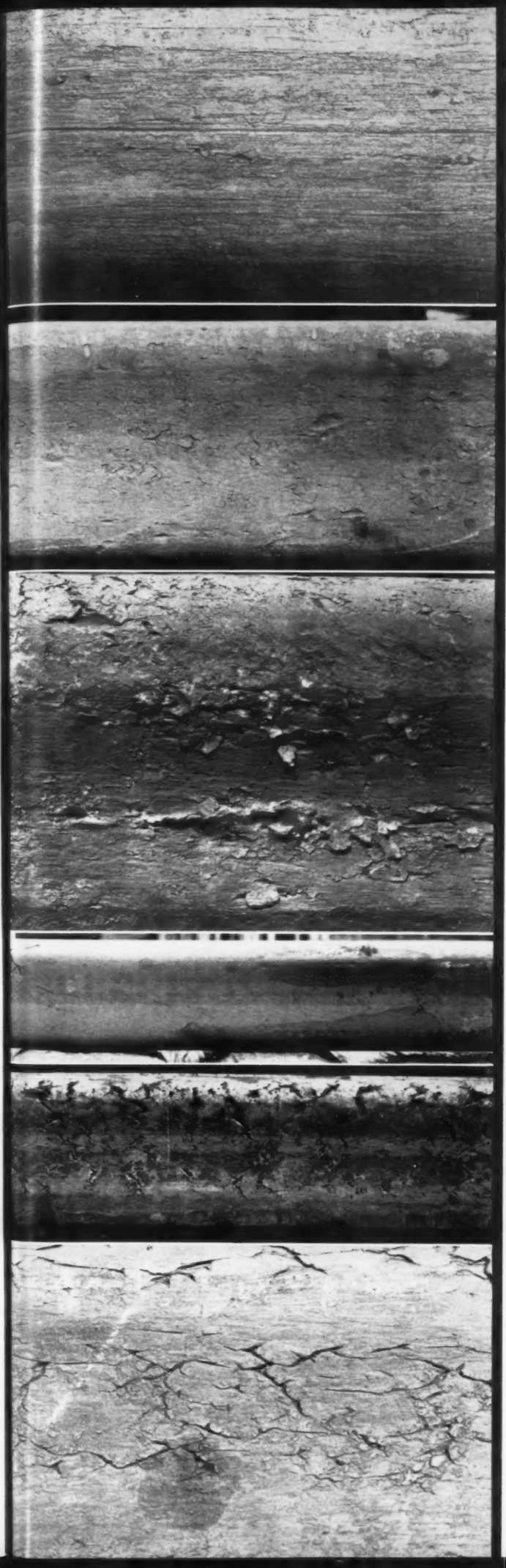


FIGURE 9

Heats with 1½ in. nozzle.

No.	Bloom size	Pounds chipped	Hours	Tons chipped per hour
1	7½ x 9	14,200	9	.788
3	7½ x 9	11,390	6	.949
5	7½ x 9	14,080	7	1.005
7	7½ x 9	14,440	8	.902
9	7½ x 9	14,430	8	.902
11	7½ x 9	13,960	7	.997
		82,500	45	

Average chipping on above heats .917 tons per hour.

Heats with 1¼ in. nozzle.

2	7½ x 9	14,040	8	.877
4	7½ x 9	14,300	28	.255
6	7½ x 9	14,010	11	.636
8	7½ x 9	13,900	17	.409
10	7½ x 9	14,060	8	.878
12	7½ x 9	12,690	19	.333
		83,000	91	

Average chipping on above heats .456 tons per hour.

steel may harden enough to make the chipping operation more costly.

The following illustrations are typical of some defects found in alloy steels and in some cases exemplify the factors discussed above.

Figure 10 shows a general seamy condition with some scabs and checks. This seamy condition may be caused by pouring variables or excessive scaling.

Figure 11 is an example of the effect of rolled in scale in producing a scabby condition.

Figure 12 illustrates a general scabby condition. These scabs may be caused by splashes during teeming and by improper mold condition.

Figure 13 shows what we call a tear. We associate tears with thin skinned ingots, underheating, or transverse cracks which are elongated in rolling.

Figure 14 shows a burnt ingot. All the ingots close to one of the port ends of a pit were burnt in this manner, while the other ingots in the pit had normal surface.

Figure 15 is a close-up of another burnt ingot.

FIGURES 10, 11, 12, 13, 14, and 15, respectively, top to bottom.

Figure 16 shows what we term a pulled apart condition. This is generally due to underheating, although at some stage of the heating the temperature may have been higher than it was at time of draw.

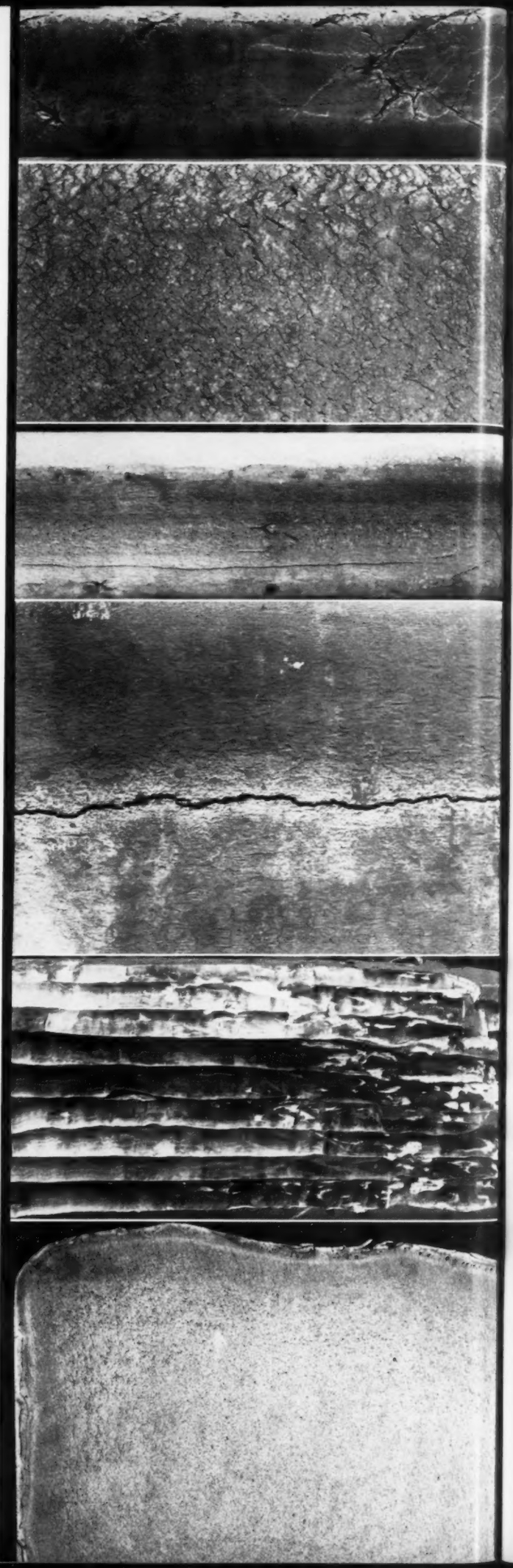
Figure 17 is typical of red shortness produced by tin contamination. The entire surface of every bloom from this heat had this condition.

Figure 18 illustrates a longitudinal crack. These may be caused by mold temperature, pouring rate, mold condition and long track time along with improper heating.

Figure 19 is what we have named a "lightning" crack. From the appearance of the fracture it may be seen that this occurred on cooling after rolling.

Figure 20 illustrates an unusual condition. The butt end of just one ingot of a heat was badly torn. On chipping the torn area was found to be underlaid with rather large elongated cavities. The etched transverse section (Figure 21) shows the laminations which have been elongated by rolling. A leaking mold plug caused this defect.

These defects have been shown in order to exemplify the variety of factors which may produce poor surface. At our works we are endeavoring to determine more accurately, not only the causes of these defects, but also the characteristics of the steel surrounding the defect, such as oxidization, decarburization, grain flow lines, etc., so that typical types of defects can be definitely identified. There have not been too much data published on this important subject and the nomenclature used is quite confusing. It is believed that a cooperative study of this subject by various plants, including the standardization of the names of defects, would be very much worthwhile to all who are interested in heating and surface quality.



DISCUSSION

PRESENTED BY

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E. E. CALLINAN, *Combustion Engineer,* Steel and Tubes Division, Timken Roller Bearing Company, Canton, Ohio.

A. J. FISHER, *Fuel Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

J. L. MILLER, *Assistant Chief Combustion Engineer,* Republic Steel Corporation, Cleveland, Ohio.

H. V. FLAGG, *Combustion Engineer,* American Rolling Mill Company, Middletown, Ohio.

R. I. GUMAER, *Combustion Engineer,* Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

P. H. BRACE, *Consulting Metallurgist,* Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

GILBERT SOLER, *Manager of Research,* Steel and Tubes Division, Timken Roller Bearing Company, Canton, Ohio.

J. R. BEHRMAN, Metallurgical Department, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.

J. D. KELLER, Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

G. M. COUGHLIN: To low carbon steel men it is very interesting to hear the adventures of the alloy part of the brethren. Our job sounds simple. I imagine you

FIGURES 16, 17, 18, 19, 20, and 21, respectively, top to bottom.

←

have a card index in the soaking pits for the numerous heating cycles.

E. E. CALLINAN: We have a system similar to that, but it is not always too complete. We have to do considerable experimental work at times. A small group of heats, as indicated by some of the charts for example, may represent our first attempts at that particular type of steel, and we have to experiment.

A. J. FISHER: I am one of those low carbon men. I don't know anything about alloys but I would like to repeat the importance of stabilizing time, as emphasized in the paper. Our maximum temperatures are probably a little higher than is shown for the low carbon steels in the paper. Our maximum temperatures run up to 2500 degrees F., and there again I am not sure whether our temperature scales are the same as shown in Mr. Callinan's paper. In other words, metallurgists have a habit of being 100 or 150 degrees different in temperature calibrations, but in any event, we do try to heat the steel to as high a temperature as it can stand without getting into burning or decarburization. The stabilizing time is a function of the time that it takes the ingot to get to the pits. In other words, if the time is three hours, we try to stabilize about two hours. If the time is four hours, we stabilize three hours in the pits. We have a number of different grades of carbon steels and we have a schedule for each one which we have worked out by trial and error to give us the best results. The general heating procedure is about the same as shown in the paper here today.

J. L. MILLER: I would like to know the number of heats forming the basis of the curve which shows rather high chipping for cold steel. Also, was the steel absolutely cold?

E. E. CALLINAN: On the charts which show the heating rates and stabilizing times each of the vertical sets of points represent only one heat. You must remember that in our shop we make hundreds of grades of alloy steels and these charts refer to just one particular pit. In some cases we still have steels for which we have not definitely determined the proper schedules. That is why only a small number of heats are shown on some of the charts. The point Mr. Miller refers to represents only one heat. We find this condition rather consistently in almost any type of steel we heat in this pit. If they are on the cold side when charged and if the stabilizing time is insufficient, poor chipping generally results.

J. L. MILLER: Is that a matter of continuous record?

E. E. CALLINAN: We endeavor to keep data on this particular pit and from it are attempting to determine heating schedules which we can apply to our regenerative pits which do not have the automatic control equipment. I might add that it is not difficult to set up typical schedules, but when you apply them to a pit which is not well controlled you still have your difficulties.

H. V. FLAGG: Our experience is altogether with low carbon steels but we do have opportunity to compare practice of a new style pit under automatic control with that of older regenerative pits on which the means of control leaves much to be desired. The results obtained on the controlled pit are decidedly superior from the standpoints of uniformity of both heating and surface preparation. The fact that conditions are stable and can be easily repeated charge after charge makes it possible to gain a much superior performance than is possible from our old pits.

The question of the style of pit which will perform best is controversial but I have rather come to the conclusion that application of temperature, atmosphere and pressure control to any style of pit will improve the performance of that pit largely because proper heating cycles, once established, can easily be repeated.

E. E. CALLINAN: I agree with Mr. Flagg's remarks on the value of control. I might add that the controlled pit, as would be expected, produces better ingot surface. However, the difference between it and the product of our regenerative pits was not as great as we had anticipated. As I have tried to indicate in this paper, there are a lot of other factors besides heating which have an effect on surface. We have found it necessary, despite automatic control, to study these other factors and to keep records of them in order to be able to account for the differences which occur. For the benefit of the combustion and fuel engineers it should be emphasized that, regardless of heating, the steel has to come to the pits in good condition if the optimum of surface quality is to be attained.

G. M. COUGHLIN: I would like to ask the authors if they have had any experience on the variable sulphur content of coke oven gas, and what effect they notice from sulphur absorption in the pits.

E. E. CALLINAN: We have no information on the effect of varying sulphur content of the gases. At our plant all of the heating beyond the open hearths is done with natural gas which has very low sulphur content and is very uniform.

R. I. GUMAER: Our modern pits are in one plant and our old pits in another, and local conditions make it so difficult to compare results that we really have

nothing conclusive. We are attempting to improve our regenerative pits, and of course, our greatest shortcoming is in total pit capacity.

I think Mr. Callinan served a point to us that long heating time is necessary for good surface results. I notice several of the heats in his curves were five- and six-hour heating time. I assume that time included the stabilization time.

E. E. CALLINAN: The pit time shown at the top of the charts includes the stabilizing time. I might state that in some cases the times illustrated are longer than might be necessary. I showed our actual data. Some of these heats were made at times of low production when the mill was not operating on full schedule and therefore it was necessary to hold the heats in the pit. Furthermore, you can't always run soaking pits according to schedule. Some heats may be cut in ahead of others, and other operating variables may cause alterations on the normal heating schedules.

R. I. GUMAER: Do you feel you have sufficient pit capacity to take advantage of the long heating that your tests have indicated you should have?

E. E. CALLINAN: Probably not, in times of high production. You would have to make some sacrifices or alterations in order to keep from piling steel all over the plant. As I said before, some of the times shown were longer than necessary. Also, the time required can be shortened by taking steps to reduce track time, heating at a faster rate, and going to the high side of the safe temperature range. Total pit time may be deceiving if comparison is being made between two sizes of pits. The pit from which our data is taken has a greater capacity than our regular pits and although the time per pit load is longer for the larger pit, the time per ton of steel heated is less.

G. M. COUGHLIN: Talking about long heat time, of course, when the monthly fuel bill comes around the boss always wants to know what happened to send the fuel bill up. You find your fuel cost goes up as stabilization time and pit time increase.

E. E. CALLINAN: Yes, fuel cost goes up as stabilizing time increases. But during the time stabilization is occurring we are at our lowest fuel input rate, so that the increase is not great in comparison with the overall fuel consumption. In our case, surface quality is of major importance and we can easily justify to the management the advantage of proper heating in order to reduce the chipping cost, which is an expensive item.

A. J. FISHER: I might add a point in that respect. We have all been going through a depression period where we have had a lot of pit capacity, more than what our orders require, for sometime, and I think we have sort of over-done this stabilization time. Not that it hasn't paid dividends, but I am wondering now in the next year or two, if conditions keep up the way they are now, whether or not we are going to turn in the other direction; whether or not our stabilizing time is going to be shortened a little bit. I think we get into these periods where we take more time than necessary and then we go the other way and take less time than necessary. We are going into a cycle now where we are going to be forced to cut down on these soaking periods. It may be that the metallurgists will devise other means whereby the overall or the resultant still will be as good. It will be very interesting to see how it works out.

G. M. COUGHLIN: We have all been under tremendous pressure on occasions, getting up a yield and keeping the costs down, and nobody has said much about tons per man hour until right now. Now it is all talk of getting out the tons, but don't forget the costs. So we will reach that compromise, Mr. Fisher, there is no question about it. We are going to have to reach it in order to get enough steel to sell. The customer's demands today in all of our plants are impressive.

P. H. BRACE: I have one question. In our organization we must deal, not with the making of steel, but with the handling of it. Soaking time is an important factor. Deficiency causes forging troubles and excess leads to high fuel costs, scaling losses, and other troubles. We assume that when we get the steel it is essentially homogeneous. However, the authors are dealing with ingots, and I would like to ask if the favorable results they have obtained by their stabilization procedure result from a closer approach to uniformity of temperature within their steel than is usual, or to improvement of metallurgical conditions due to homogenization, *i.e.*, elimination of composition differences generated during the freezing of the ingots.

E. E. CALLINAN: I would say both. I think I should re-emphasize that some of the long times shown are not according to schedules we have set up. I don't want to leave the impression that stabilization time versus surface quality is a straight line function, and that as you increase your stabilizing time your steel is going to keep getting better. I illustrated one case where excessive scaling, caused by long time, increased chipping costs. There will be an optimum point between the two factors.

With some steels where there is a range of safe heating temperatures, you can take them to the high side of the range, reduce the stabilizing time, and get the desired result.

GILBERT SOLER: I might add to Mr. Callinan's discussion. Certain types of steel do tend to segregate more than others, *i.e.*, the high nickels, chrome nickels, chrome, chrome molybdenum and chrome nickel molybdenum steels. They form a pronounced columnar structure. If one would analyze the different portions of the ingot a variation in analysis could be found. The segregated structure can be diffused back to produce a more homogeneous steel casting by high temperature treatment. It takes quite a bit of time at high temperature to reduce segregation. I would say a 19 inch ingot requires 6 to 8 hours at 2200 degrees F. to have a definite effect.

In addition to the diffusing treatment, a normalizing treatment, that is, cooling to room temperature and reheating through the critical range is helpful in reducing segregation before hot working.

J. R. BEHRMAN: I don't quite understand the distinction between the tearing and pulling apart and the causes for each type of defect. Also on this rolled-in

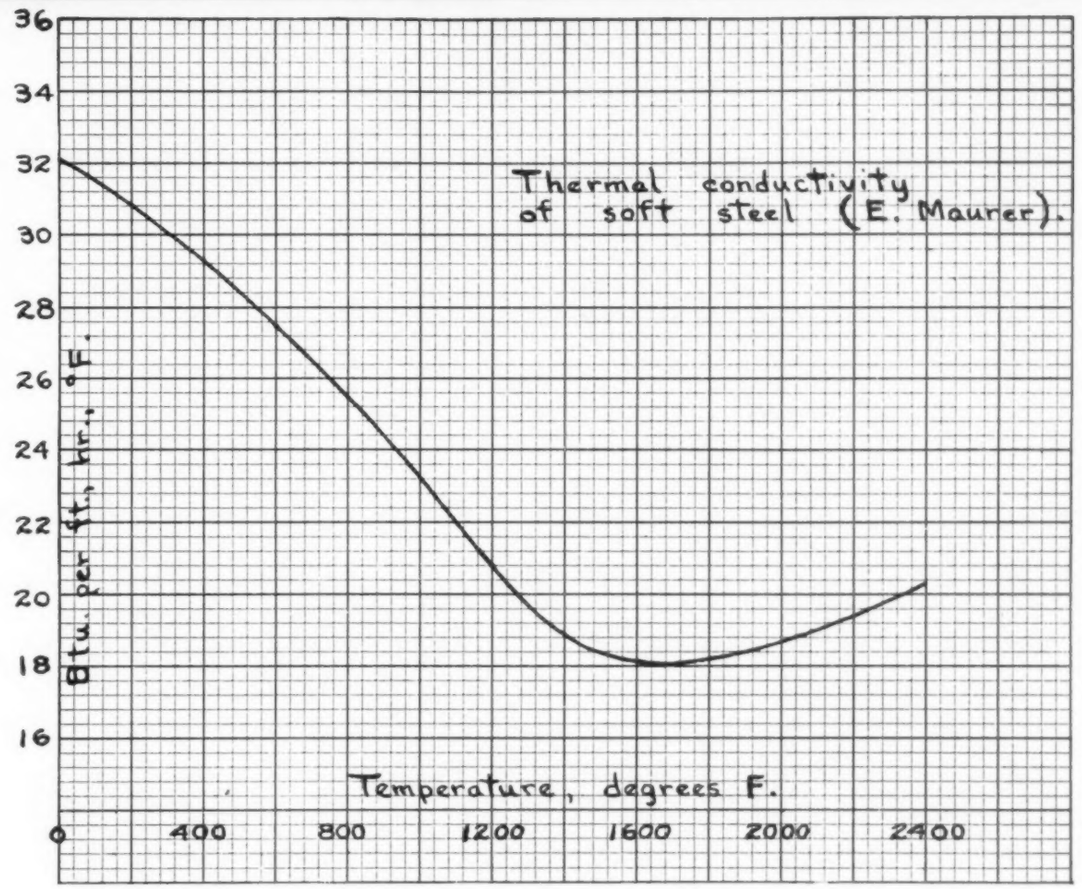


FIGURE A

scale, I wonder if you would tell us what kind of seam that causes. Is it a long seam or just a short brush seam or pock mark?

E. E. CALLINAN: In general, those seams are not very long. They may vary from a small seam, approximately one-half inch, to some running as much as 6 or 8 inches. Figure 10 illustrates this type of defect.

I am sorry I can't tell you much about the characteristics of each type of defect. At the present time we are just in the process of studying them and attempting to find differences within the steel surrounding the defect. In some cases, for example, there may be a large decarburized area around the defect. In others the decarburized area is found only at the base of a crack or other defect. The grain flow may be horizontal to the bloom as it approaches the defect, or it may tend to turn and follow the defect.

Such data has not been included in this paper because we are not yet in a position to draw any conclusions. It is a very interesting investigation and at a later date we hope to have something to contribute on the subject.

J. D. KELLER: With reference to the calculation of the temperature-time curves of Figure 3, it should be stated that the thermal conductivity values given apply only at low temperatures. As the temperature rises, the conductivity drops off. According to E. Maurer, in the case of soft steel there is again a slight increase at temperatures above 1700 degrees F., as shown by Figure A, but at an average temperature of say 2000 degrees F. the conductivity is less than 60 per cent of the value at room temperature.

In the alloy steels, there is some indication in the few data available that the thermal conductivity does not drop off as fast, with increase of temperature, as it does in plain carbon steel. This would mean that the difference in the closeness of approach of the center-temperature curve to the surface-temperature curve in Figure 3, as between the alloy steel and the carbon steel, would be smaller than appears in that figure; although the actual temperature difference would be greater in both cases. To the best of the writer's knowledge, no data on the conductivity of alloy steels at temperatures above 1600 degrees F. are available, hence no definite conclusions can be drawn as to the temperature difference on the basis of calculation alone. Actually measured temperature-time curves for the alloy ingots are very much to be desired, although it is realized that the difficulties of measurement are extremely great.

Modern MAINTENANCE *Practice*

T. R. MOXLEY, *General Master Mechanic*

WHEELING STEEL CORPORATION

STEUBENVILLE, OHIO

Presented before Pittsburgh District Section
Pittsburgh, Pennsylvania, November 20, 1939

▲ MODERN maintenance, particularly in steel mills where the finished product is manufactured from the raw materials, involves a combination of many factors presenting entirely different angles from which maintenance must be considered, yet all terminating in the ultimate result of production and cost.

The first and most important duty of the maintenance superintendent of such a plant is in the selection and training of those men who are to assist him in properly planning and supervising the work to be done. Herein lies a great responsibility, as a step in the wrong direction will not only produce disastrous financial results and sleepless nights, but also break down the morale of that particular unit in which the mistake is made, a condition which is not only embarrassing but difficult of solution. The common fault in this connection has been overloading our key men, as our ambitions at times lead up to the delegation of responsibilities that become burdensome, and instead of the desired successful accomplishment our efforts result in failure. Maintenance foremen in production departments can be compared to a servant serving two masters, the operating department on one hand and the maintenance department on the other. His obligations and responsibilities can be greatly minimized by close cooperation of these two department heads.

Modernization of maintenance methods has kept pace with modern production methods, due only to the untiring efforts of those men on whom is placed the responsibility of selecting and training their key men, and organizing definite educational programs where concrete examples are considered and analyzed to a successful conclusion.

In this connection, in planning particular schedules of major repairs that involve a mill shutdown, we are usually required to estimate the time necessary to complete the work. This is very essential, as the operation of one mill in many instances is so closely interwoven with that of other mills. In the event the repair schedule is prolonged it is obvious that the operation of all mills thus connected will be greatly jeopardized. Unfortunately, there are instances where this has been the case, sometimes due to unforeseen conditions that developed and could not be analyzed until after the actual shutdown. On the other hand mistakes have been made due to improper analysis or estimating. Such cases are those examples to be considered and analyzed in order that similar mistakes will be avoided in the future on work of a like nature.

During the past ten years, commonly referred to as the recession years, we have had little or no opportunity in which to train men for the key positions, as our forces were usually necessarily kept at a minimum. Also, during this period, much modern equipment has been built. Therefore, the responsibility and necessity of training man power is greater today than ever before. With such modern machinery as we are called upon to service today, wherein all parts are closely fitted, with small tolerances, the maintenance problem has graduated from the sledge hammer and monkey wrench phase to that of higher skilled mechanics wherein precision and accuracy must be the watchword.

It has been my experience that with few exceptions, the shop trained men given the opportunity of a reasonable amount of mill experience will result in the better key men for mill maintenance than the man who has had no shop training, with technical training and other experience being equal.

Having satisfied ourselves that our key men, so far as their mechanical ability is concerned, are competent, we still have that ever-present problem of dealing with people, commonly referred to as handling men. For reasons known to most of us, this is one of today's biggest problems and requires cool, level-headed thinking; also a little time spent in the study of psychology will be of great assistance. New thoughts in this connection should be presented at the foremen's regular weekly meetings.

Selection of those men who actually perform the work is likewise of great importance, as from these men we naturally expect to draft our key men of the future. Man power of this caliber is not always available and this fact presents a problem for the foreman in contacting new men. Every precaution should be exercised,

and only those selected who display an intelligence that will insure a rapid assimilation of the maintenance problem.

The success of a maintenance department depends primarily upon an organized system of inspection. The duty of making inspections must be definitely assigned to specific persons, preferably sub-foremen, who in turn submit written reports to the general foremen. Unfavorable conditions are given special attention and corrected at an opportune time, *i.e.*, roll change, etc. If the repair involves more time than a roll change would provide, very effort is made to avoid a delay and the repair placed on the schedule to be made on the regular week-end shutdown, such as are common in most rolling mills.

Every convenience possible should be provided for facilitating maintenance work. Departmental tool rooms and capable attendants are indispensable. All tools should be stored and kept in good condition, a check system being used to insure the return of the tool; also the necessary jigs and fixtures provided for special jobs should be cared for. A portion of the room might well be arranged for storage of standard bolts, pipe fittings, packings, small repair parts, etc., for immediate use.

Likewise, provision must be made for the proper storage of large spares, which should be properly catalogued. A metal identification tag, upon which is stamped the drawing and piece number and its location in the spare building is attached to the spare, and an index card system in the departmental mechanical office provides a complete record of all spares and their location. When a spare is used the metal tag is placed with the identification card in the office file, and an order is issued for the replacement of the spare. Upon its receipt the metal tag is attached and the spare stored in its proper place in the spare building. This system, due to its simplicity, has proven very effective.

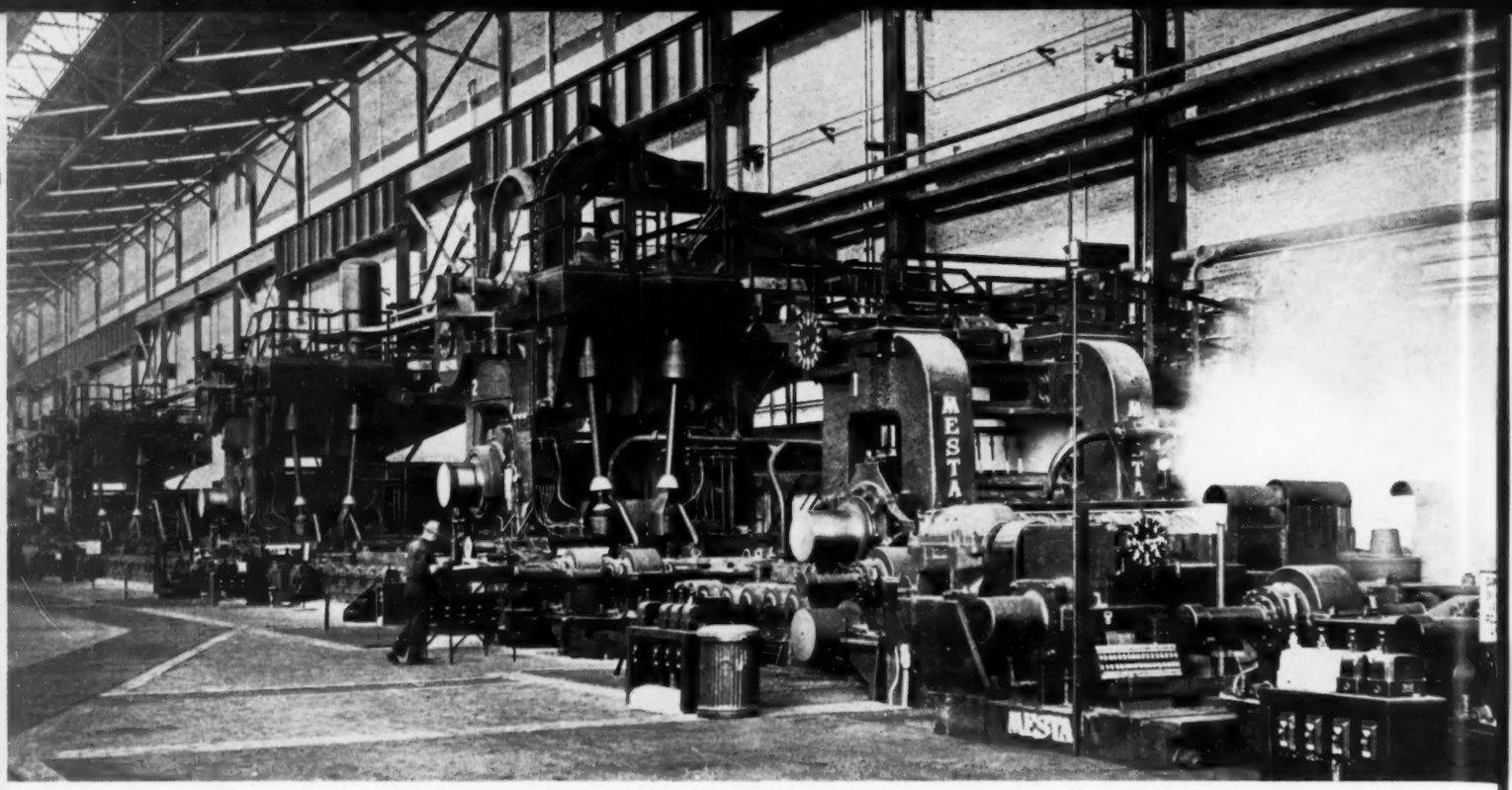
In larger departments, a clerk is usually employed in the mechanical office, his duties being that of time distribution, keeping records, ordering and expediting material, etc. To him is also delegated the responsibility of the proper care and storage of repair parts.

In continuous operations such as by-product coke plants, blast furnaces, open hearths, gas-fired boilers, etc., it is very necessary that close inspections be made daily and minor repairs made without interruption to operation. This can usually be done by the cooperation of the operating and mechanical departments. If the repair is of such nature as to require a shutdown, this time can also be minimized by the same cooperation, as there are usually tuyeres, coolers, blow pipe, etc., at a blast furnace that require changing, and at the open hearth, such jobs as front walls, roofs and rebuilds, at which time major repairs can be made. By-product coke plants are usually equipped with such spare equipment, *i.e.*, larry cars, door machines, pushers, quenching cars, etc., which practically eliminate oven delays. The coal handling section requires constant inspection, as here the possibilities for delays are greatest; damage to conveyor belts, coal screening units, etc., can be caused in many ways. A delay in this department disrupts the operation of the entire plant. Mechanical repairs in this department must be planned very accurately, as only limited stops can be made. In the by-product and benzol departments, duplicate equipment is usually available. Here mechanical maintenance is comparatively easy when proper inspections are made.

It is customary in rolling mills to shut down either each week-end or at other predetermined periods, for changing rolls, mill sections, etc., at which time mechanical repairs are made. In hot strip mills particularly, this shutdown period must be studied and planned very accurately, as all backup rolls, roughing and scale breaker rolls are usually changed, which is done by mechanical repairmen. This, in addition to the necessary mechanical repairs, involves a job of no small proportion. An item of great importance in arranging this work schedule is the service available from overhead cranes, so that men may be placed to the best advantage to avoid lost time due to the lack of crane service. During these periods, additional men are required over and above those regularly employed in this department. These men are taken from the shops department in proportion to the class of work at hand. It has proven very advantageous in selecting these shop men to select those who readily adapt themselves to this class of work, and it will follow that, with a reasonable amount of training, you will have built up an organization that will lend themselves to greater efficiency, in which teamwork, quality and quantity will be improved, and lost production time will be materially reduced. It follows that shop schedules must be arranged so that these same men will always be available for mill repair periods. Organizing for this work is of vital importance, and close cooperation with the operating department will aid materially. During the time intervening between repair periods, notes are generally kept from daily inspections, and a schedule prepared from which all material is made ready and the number of men required ordered from the shops at least one day prior to the shutdown period. Practically all steel mills have a well organized shops department, some much better equipped than others. Herein lies the heart of the maintenance department, and while during recent years great progress has been made in the improvement of shop practice and controlled costs, there still remains a tremendous job to be done in bringing our shops up to that standard of perfection which we feel is quite possible.

Here again, we find ourselves face to face with the problem of continually training men along the lines of better methods and creating interest in the individual to the end that the work at hand is being done as a matter of accomplishment and not only for the compensation it represents.

In addition to the established hourly base rate, many shops operate on the incentive or bonus system. However, the value of this system is debatable, inasmuch as it has proven successful in some shops and failed in others. There has been some controversy and difference of opinion on the question of location of shop equipment. There are those who support the idea that a certain amount of shop equipment should be installed in each operating department, while others contend that the centralized system is preferable. It would seem that this is a matter in which the geographical layout of the plant should be considered. In the larger plants where departments are separated from each other by considerable distance, the necessity for a limited amount of shop equipment in each department is justified, otherwise the



Mechanical refinements in the steel plant equipment of today call for a totally different maintenance technique requiring precision and high mechanical skill.

centralized system would seem to be the most economical.

Considering again the matter of modernizing shop practice, we are greatly indebted to the machine tool builders for the excellent progress they have made in modernizing shop tools, and to the tool steel manufacturers for the improvements made in higher quality tungsten carbide tools, thereby making possible higher cutting speeds.

Practically all shop departments are operated on a budget system based either on total man hours in the entire plant, or on total tonnage produced. We prefer the former, as this system provides a given rate per hour for each shop based on the total man hours worked in the entire plant, and provides a given amount of shop budget regardless of tonnage.

A system of ordering material from the shops is usually provided, but whatever system is adopted, expediting is necessary. The shop expeditor is contacted daily by those ordering material. By this system work is scheduled through the shops and delivered to the several departments, and is usually on hand when needed. The system of shop ordering that we find best adaptable to our particular set-up, after having tried several, is the one by which the department ordering material issues the shop order in duplicate with all necessary information and drawings, both copies of the order being sent to the shop office where it is given a number. One copy is retained in the shop office and the other returned to the point of origin. The shop copy is handled by the expeditor and additional copies of the order are made for as many shops as are involved. When the work has been completed, the original order is returned to the foreman who ordered the material, the order showing date of completion.

A hauling order is issued to the transportation department for delivery of the material. Each department in the plant has its specific charge account, as well as each unit in the department, making it comparatively easy to check the cost of any job at will.

In addition to the regular running repairs, there is always more or less construction work going through the shops. This work usually originates in the engineering department and is handled by shop orders in exactly the same manner as the regular repair work. We find that, owing to the simplicity of this system, office personnel and routine are reduced to a minimum.

Not only are the shops operated on the budget system, but likewise the mechanical groups in each department. However, this budget is based on departmental tonnage.

In organizing mechanical units for departmental operation and repairs, commonly referred to as mechanical labor regularly employed, precaution must be taken not to over-man the unit as this will result in excessive costs. Only a sufficient number of men to perform the immediate running repairs, effect proper lubrication, make inspections, fit up spares, etc., are necessary. These men are usually classified as first, second and third class, and their rates vary accordingly.

In our efforts to minimize maintenance costs, we are greatly indebted to the progress made by the metallurgical engineers in perfecting materials of greater strength and wear-resisting qualities, wherein capacities have been practically doubled per square inch of section; also to our foundry operators in alloying metals for a specific purpose, *i.e.*, heat resisting iron, high lead

content bronze, acid resisting metals, etc. In all well organized foundries of today, a continuous program of research is in progress. Iron castings, where it is possible, are being replaced by steel, but alloyed iron still has its place in the industry. Few castings, if any, are made from gray iron. High-strength irons are being produced by mixing steel with the iron in the cupola in various percentages, and in many instances the addition of alloys, such as nickel, chromium and molybdenum, are required. These castings must be properly heat treated, preferably in a furnace equipped with automatic temperature control. A few specific items may be of interest: Radiant tube portable annealing furnaces originally were constructed with a refractory base topped with a steel plate which supported the pack of steel sheets to be annealed. This steel plate was very unsatisfactory, due to warping, and an alloyed iron casting was designed and made to permit perfect heat circulation, the analysis being 60 per cent selected steel scrap, 20 per cent pig iron and 20 per cent high grade scrap, such as riser heads and gates from similar castings. The mix was adjusted to permit the addition of 1.25 to 1.50 per cent nickel, and .90 to 1.20 per cent chrome, they are heat treated before machining. These castings, after many months of service, are in perfect condition. Dies for upsetting machines commonly used in tube mills for extruding the ends of seamless tubing, formerly made of die steel, have been replaced, using an alloy of 75 per cent selected steel scrap and 25 per cent pig iron, the mix being adjusted to permit addition of 1.25 to 1.50 per cent nickel, 1.00 to 1.25 per cent molybdenum. We might add that while molybdenum does not have the high heat resistance of chromium, it adds strengths to the metal and can be used satisfactorily where temperatures do not exceed 1000 degrees F. Castings of similar analysis are being manufactured for hot strip mill edging rolls, apron plates, pistons for gas and diesel engines, grate bars, etc.

In the production of bronze castings, only virgin metals or scrap of a known analysis should be used. Aluminum, manganese and leaded bronze are manufactured for general steel mill maintenance. Some castings are die cast or made from metal patterns and are cast to size, thereby eliminating machine work. A problem in bronze that required considerable research and may be of interest was that of manufacturing hot strip mill spindle slippers. Considering the fact that the spindles are only 33 in. from center to center of slippers, obviously excessive wear is prevalent as compared with mills of greater spindle length. At present, spindle slippers are being made of an iron-aluminum-copper alloy, heat treated. The iron, added as steel turnings, is charged into the crucible with the copper, the amount varying with the section and averaging between 1 and 5 per cent, with virgin ingot aluminum 10 per cent. This bronze is by far the most satisfactory for this service. Acid resisting bronze castings, some of which have been in service for 11 years and are still in perfect condition in by-product and pickling plants, are made of 70 per cent copper, 20 per cent lead and 9 per cent tin, with 1.5 per cent nickel.

Alloy steels, such as are available today, will, when properly applied, aid materially in solving many maintenance problems. As a general purpose alloy steel for the manufacture of drive shafts, pinions, screws, axles, etc., SAE-3135 will be found very satisfactory and inexpensive.

Welded construction, upon which many interesting and educational papers have been presented, continues to progress rapidly. Maintenance costs and operating delays are materially reduced by the application of this science. Likewise, volumes have been written and presented on the subject of lubrication, and will continue to be, as this phase of maintenance presents daily problems that require diligent investigation and study.

In conclusion, if we are to succeed in our work, ours must be an attitude of progress. We cannot be satisfied with present day accomplishments. Constant application to the study of improving methods, perfecting machinery to a higher degree of efficiency, and training of mechanical personnel is of paramount importance. This can, and is being accomplished today as never before.

DISCUSSION

PRESENTED BY

F. H. DYKE, *Superintendent*, Blooming, Bar and Hot Strip Mills, Wheeling Steel Corporation, Steubenville, Ohio.

J. B. WHITLOCK, *General Maintenance Engineer*, American Rolling Mill Company, Middletown, Ohio.

H. L. DAWSON, *Engineer*, Repairs, Maintenance and Lubrication, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

T. R. MOXLEY, *General Master Mechanic*, Wheeling Steel Corporation, Steubenville, Ohio.

E. W. TREXLER, *Superintendent of Maintenance*, Bethlehem Steel Company, Johnstown, Pennsylvania.

J. M. MORRIS, *Superintendent of Maintenance*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

H. B. CONOVER, *Chairman*, Maintenance Committee, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania.

HARRY D. ROBB, *District Manager*, Industrial Division, Timken Roller Bearing Company, Pittsburgh, Penna.

H. H. SHAKELY, *General Master Mechanic*, Strip Mills, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

J. S. GREEN, *Master Mechanic*, Edgewater Steel Company, Oakmont, Pennsylvania.

E. H. BEATTY, *Superintendent of Maintenance*, Allegheny-Ludlum Steel Corporation, Brackenridge, Pennsylvania.

H. E. REITH, Brooks Oil Company, Pittsburgh, Pennsylvania.

A. W. STEED, *Superintendent of Maintenance*, American Rolling Mill Company, Middletown, Ohio

F. H. DYKE: Maintenance costs largely are caused by five elementary things: faulty operation, natural wear, improper inspection, faulty lubrication, and design of equipment. Most of us have had equipment designed beautifully to do the work for which it is intended, but

when it wears, oftentimes it takes four or five hours to tear it down to get at a bearing or a clutch, or some other simple thing that can be fixed in possibly 10 or 15 minutes. After that happens once we change the design so that when it occurs again it is easier to get at. Frequently we forget to pass this information back to the man who designed the equipment. If that were passed back to the manufacturer he could take care of these details in new design, and we would help ourselves out in future purchases of similar equipment.

J. B. WHITLOCK: I think that we owe Mr. Moxley our very sincere thanks for his very remarkable paper, "Modern Maintenance Practice." In my opinion he covered this rather difficult subject very thoroughly. He has brought to our attention a series of points which present to all of us large and important problems: personnel and training, inspection, repair schedules, tools, spares and spare records, shop schedules, shop budgeting according to operating hours and control of the product of the shops. We must admit that this list of items thoroughly covers the maintenance field in any plant.

To me, the most important of the items is inspection. To successfully cover the maintenance in any plant, whether it be a steel mill or a job shop, a program of preventative maintenance must be followed. Such a program must be built around a well organized system of inspection. Throughout Mr. Moxley's paper, reference is made to inspection and the importance of this function in aiding him in maintaining the equipment in his plant.

If we carry home with us this one point, inspection and the intelligent application of the data on the inspector's report to a well organized repair schedule, we will have gained a great deal from Mr. Moxley's paper.

H. L. DAWSON: I enjoyed the paper very much and agree with Mr. Whitlock's remarks on inspection. One of the things that confronts most of the maintenance men in industry is the training of men. The increased number of apprentice training, foremen conferences, and other educational activities has not been able to offset the effect of curtailed operation, and of the thousands of applicants, only a very few have had any experience.

E. W. TREXLER: Mr. Moxley's paper was very interesting; it sounds almost as if we were talking over our own problems at home, which are very similar. The only point I would like to add is that it is very important for any maintenance department to have a man who is competent to follow costs. For instance, all maintenance men realize at times that we are spending too much money on a certain piece of equipment; and on going back to find out how much we have spent, our records are vague and it is difficult to show the actual expenditures. If we have a man who is familiar with costs, and can follow the repairs on certain items or wearing parts, there is no doubt that many a time we can save money by replacing the equipment in question.

T. R. MOXLEY: That is a very important item and I am glad Mr. Trexler has brought it up. So far as knowing what a job costs, that is very easy to find out any time you wish to know. The most important thing in that connection is to have a man in your department who, after a time, becomes familiar with what costs should be and keeps his eye on that cost book, not once a month but every day. We have a system in our office whereby within two minutes, we could tell you the cost of any piece of machinery that goes through our shop. It all depends on the man in that case. As maintenance superintendents, we are all quite busy, and unless you have someone on whom you can depend to call your attention to excessive cost figures before they go too far, you will get into the leaks before you know it. We should have a man who calls our attention to those things before, not after, the trouble occurs, so that something may be done about it.

J. M. MORRIS: I would like to ask Mr. Moxley how he controls his orders on his shops to know that all his orders are actually needed at the time. I think you will agree, unless your shops are extra large, that you will find you have a lot of old orders on your hands, especially when a depression comes along. Some of those orders may become a year or more old. How do you control that to know whether you actually need those items when they are placed?

T. R. MOXLEY: The same gentleman I previously mentioned, every two or three weeks, goes through our shop orders, and when he finds an order six to eight weeks old, he will look up the man who sent the order back and ask him whether or not he needs that material. Those orders, if the expeditor is trained correctly, should not accumulate to any great extent.

H. B. CONOVER: Mr. Moxley has stressed various branches of maintenance that are necessary to the successful operation of a maintenance department. There is one other, however, that perhaps has not in the past been given the importance it deserves as a necessary part of maintenance work. That is, performance records made for the use of maintenance men; records that will indicate those points that are requiring more than their share of labor and material as compared to all the other facilities. An example of this is apparatus life records. Such data gathered without unnecessary detail are essential to the intelligent direction of the maintenance department's efforts.

F. H. DYKE: The point Mr. Conover raised is one that is getting harder and harder to get all the time. The management wants costs on the first of the month, and not in too much detail. The maintenance man and the operator want more detail as to what each item of equipment is costing. However, it should not require too much work to obtain satisfactory records for all needs.

H. D. ROBB: During a recent visit to Steubenville, Mr. Moxley showed me a new bearing enclosure that he had developed. The major reason for premature failures of bearings is due to inadequate enclosures. I thought Mr. Moxley would describe this enclosure in his paper. I feel certain that all the operating men would be interested in hearing about this seal. If he has no objections, I would appreciate Mr. Moxley's describing this seal as we all realize that better seals will reduce maintenance.

T. R. MOXLEY: In our strip mill, the back-up rolls are equipped with roller bearings, and, of course, if there

is anything in the world detrimental to roller bearings of any kind, it is Ohio River water. We do not have so much trouble in lubricating the top back-up roll, but bottoms are difficult to lubricate, not so much the bearings, but rather that portion between the inside diameter of the bearing and the roll neck itself. The clearances between those two surfaces are so small that you cannot get a lubricant between them without pressure. It becomes necessary then to design an enclosure or seal ring, as we call it, wherein pressure can be built up inside the bearing, forcing the lubricant through the channels which are provided between the bearing and roll neck iteslf and reducing, insofar as possible, the wear between the bore of the bearing and the neck of the roll. We all know that, even though the inner race of a bearing may not be supposed to move on the neck, they do move just the same. You have that creeping action all the time on the inner race of the neck of the roll, because they are not shrunk on or put on extra tight. Therefore, it is necessary that lubrication finds this space between the bore of the bearing and the neck. Bearing that in mind, we have developed a seal ring wherein we are actually able to get pressure. On the first one of these seal rings that we installed, we were able to reduce the amount of lubricant going into that bearing by about 30 per cent. When we removed the bearing from the neck of the roll, at the time of a ten-day shutdown period, we found it was perfectly lubricated. In view of that, we have proceeded with the manufacture of additional oil seals, and are installing them on bottom back-up bearings as fast as we can. The construction of this seal is nothing more or less than a channel in which a three-piece metal ring is inserted. The outside diameter of this three-piece ring has a groove cut away, and all around there is a garter spring that is doweled in the casting to where the ring remains stationary. However, the seal in the ring is free enough to permit easy action and really does not bind on the joint. Consequently, as wear takes place inside the seal ring, the garter spring which we have attached to the outside of this ring is constantly compressing the ring in toward the roll neck. This three-piece ring is constructed similar to the old-style piston ring and is placed in with very little clearance. Since we have found this will do the job, naturally we are anxious to complete this as quickly as possible. We feel it is going to be the answer to welding back-up roll necks and regrinding.

H. H. SHAKELY: In the three piece garter spring type ring, is the ring so fitted that it clamps the roll with clearance at the cuts, or is there clearance between the roll neck and the ring?

T. R. MOXLEY: The inside ring is fitted with about .006 in. clearance and it is fitted with a butt joint. With a three-piece ring you get uniform wear all around.

J. S. GREEN: Relative to the remarks Mr. Dyke made about change in design being reported back to the manufacturer, if we redesign something that has merit, I think it should be passed on to him. As an illustration, several years ago we had some power equipment tripped with a very sensitive foot lever and it had to have very delicate adjustment. We conceived the idea of putting an air cylinder on to get away from that. A short time later the advertising of the manufacturer of the equipment in question showed the application of our air cylinder.

E. H. BEATTY: We had quite a lot of trouble with the inner race of a roller bearing in a mill in 1928. The manufacturer's representative came up quite often. We started out with .006 in. clearance and ended up with about .30 in. Right now we find, at high pressure, we can lubricate that roll and have not had trouble since. All the seal rings we use are to keep water, scale and dirt out; if we can keep the dirt out we can keep the grease in. If any of you gentlemen find it difficult to lubricate a roll, try that and you will get away from your trouble.

Due to conditions existing in the last ten years we have had considerable trouble developing maintenance men, both mechanical and electrical, to a place where he can supervise all men in his department. I do not like to have a man to supervise just in mechanical or electrical work, but to handle both.

For emergencies and new work in departments we have our various maintenance men, which are supervised by an experienced man in his own line of work, such as, crane repair, electric linemen, millwrights, pipe fitters, etc.

As to cost, which we are always checking, I have adopted a plan whereby I am telling all men that are handling equipment the cost of such material. Most of these men do not realize the price of material. In doing this I have noticed remarkable results.

H. E. REITH: Having had the pleasure of working with Mr. Moxley for about eight years, I think I can confirm everything he said. Maintenance is a big job. I will say that, in the last four years, I think more progress has been made in maintenance, inspection, and lubrication than had been made in twenty-five years prior to that time. In those days, about 20 per cent of the apparatus was tied together with lumber, patches, and bailing wire. Today if we go into a mill and see something like that, it sticks out like a sore thumb. Maintenance men are on their toes to avoid just that.

One item Mr. Moxley remarked about was loading up our key men. I do not mean the master mechanic; I know the master mechanic is in charge of more than one department, but the man under him, and again the man under him. In many plants I go in today, I hear these men say, "Had an all night job last night and I can hardly hold my head up today." Several plants are putting on a night master mechanic to relieve these men, with assistants to do the little things. Too many times the operators will have a little job and will call out the day man to see if he can do it. This in itself shows poor planning.

A. W. STEED: If maintenance men could gather around a table more often, to discuss their mutual problems, great benefits would result. Mr. Moxley in his paper has covered the ground very thoroughly regarding training of men, organized inspection, and planning of work.

The plant with which I am connected is in a small town where skilled men are at a premium, and we have been forced to train a large number of men through training classes and apprentice courses. These training

courses have been applied in the shops, power division and assigned maintenance departments with excellent results.

One group of approximately forty men have been taking an electrical training course and a laboratory is being developed where these men can have practical experience in tearing down and connecting various types of equipment.

Mr. Moxley has not mentioned insurance maintenance, and my wish is that some one invent a slide rule or devise a formula that will tell us the number of spares to carry so as to satisfy both the operating men and the management at the same time.

MEMBER: Under the budget system, doesn't the maintenance department suffer? What do you base your maintenance cost on?

T. R. MOXLEY: They used to tell us that the only way you can budget mechanical labor was on a tonnage basis. I did not always believe that. There are departments which do not produce any tonnage, but still they operate and we have to maintain them, such as power houses and rolling stock that have to be maintained whether a ton of steel is made in the open hearth or not. With that in mind, after a lot of consideration at our plant, we decided that we could work out a shop budget system based on total operating man hours, which we proceeded to do. We attacked this problem by selecting a time (and to be specific, it was in May, 1937) when we were running at a very good rate—not 100 per cent, but around 70 or 75 per cent—and upon those figures we arrived at what we had to do, and it has worked out very successfully. Even though our tonnage would be low, we still have some budget on which to operate the shops. This is the way it is set up. The time allowed in our machine shop is 4.33 hours for every 100 total man hours operation in the plant. For every 100 total man hours in the plant, our rigging gang is .38 of one hour, and so on. We are always one day behind on that, because it takes that long to get figures through the cost department and back to our office, at which time the shop foremen are informed what their budget is for the next day; and in this way we have been able to operate in the black nearly all the time. There are times when excessive repairs are necessary and we will get in the red. The only thing I do not like about the system is that, where we still have a few thousand hours in the black at the end of the month, we are not permitted to carry over into the next month. Nevertheless that is the system on which we are working our shops now.

In the operating departments where tonnage is produced, the maintenance hours are set up on a tonnage basis, or man hours allowed per 100 tons. Our foundry being a producing unit, is based on its own tonnage for the man hour budget. The open hearth is allowed 6.27 man hours for 100 tons of steel; the hot strip 13 man hours per 100 tons; cold mill 13; tube mill 25, etc.

J. B. WHITLOCK: We have a little different system in controlling our shop and field maintenance man hours with relation to the operating hours than Mr. Moxley has outlined.

About five years ago, a study was made so as to determine the shop and field maintenance man hours that were required to maintain each piece of equipment in the plant. This study covered a period of three years and as a result, a rather wide range of operating rates were recorded. From this data, a curve was drawn for each piece of operating equipment and from this curve, it is possible to obtain a factor of allowed shop or field maintenance man hours for each operating hour of the equipment.

Our plan calls for weekly schedules, and on Thursday of each week the production department furnishes the maintenance department with the operating hours that will be employed for each piece of equipment for the following week. The maintenance department then applys the factors that have been developed on the charts and arrives at an allowed maintenance man hour for each piece of equipment. This information is then given to each field maintenance foreman and he in turn schedules his field men and the shop hours that he is allowed. This sounds like a big task, yet after the system had been in operation for a few weeks, it became a matter of routine and likewise a very valuable tool for the maintenance supervision. The value of this system lies in the fact that it first requires the maintenance foreman to carefully plan his work; second, it supplies the maintenance superintendent with accurate cost trend data daily; and third, it quickly flags any piece of equipment that is receiving excessive repair.

H. H. SHAKELY: We have been trying to lubricate our spindles, and have one blooming mill running now close to four years; but on strip mill we have not been successful in spindle lubrication. We started out with hand greasing. We have tried to enclose pinions and slippers. Our roll end cannot be covered, as there are at times three or four roll changes in a short period. Is there any better method than the hand-greasing method?

T. R. MOXLEY: I have not found anyone who has a better method than you use. It presents a problem of providing a material that will wear the longest without lubrication. In checking up on some slippers in our own foundry, we have some that have run 430,000 tons and are still in there. We try to lubricate those things and it is impossible. You have to find a metal that will give you the longest service without lubrication.

H. E. REITH: In connection with lubricating slippers on spindles, I recently heard of a scheme using a metal cover. It is a spiral telescopic metal cover for the pinion end and roll end. It is a matter of loosening up two set screws and sliding the cover back, and then slipping it back into place again, applying a little grease until the next roll change. It does two things: it keeps grease in and keeps dampness out

In the past I don't think enough attention has been given to lubrication of these slippers. You fellows can aid yourselves materially by the selection of proper lubricants and applying them in an efficient manner.

To the Younger Men in the Iron and Steel Industry:

The Constitution of the Association of Iron and Steel Engineers was recently revised. Included in the revisions is a classification of membership designed to fill the demands of the younger men in the iron and steel industry. This classification is known as JUNIOR MEMBER.

Under the revised Constitution JUNIOR MEMBERS shall be citizens of the United States or Canada and shall be persons identified with the Iron and Steel Industry, not less than 18 years of age and not eligible to membership under any other classification. After the age of 27 years, one's classification automatically becomes Active or Associate, subject to the approval of the Board of Directors. The yearly dues are changed accordingly and no entrance fee is required to make the transfer.

Annual dues for JUNIOR MEMBERS are five dollars. There is no entrance fee. JUNIOR MEMBERS are entitled to the monthly issue of the *Iron and Steel Engineer,* the official publication of the A. I. S. E., the privilege of attending all district section meetings (in Chicago, Birmingham, Detroit, Cleveland, Philadelphia, and Pittsburgh), the privilege of attending the Annual Convention and Iron and Steel Exposition, the Spring Engineering Conference, and the regular inspection trips to steel plants.

For full particulars please address inquiries to your nearest District Section office:

Birmingham District Section: Birger Thele, Tennessee Coal, Iron and Railroad Company, Pratt City Station, Birmingham, Alabama.

Chicago District Section: A. J. Whitcomb, 310 South Michigan Avenue, Chicago, Illinois.

Cleveland District Section: W. W. Spanagel, 1080 Ivanhoe Road, Cleveland, Ohio.

Detroit District Section: Elmer Weiss, 2755 East Grand Boulevard, Detroit, Michigan.

Philadelphia District Section: Linn O. Morrow, Schaff Building, Philadelphia, Pennsylvania.

Pittsburgh District Section: Brent Wiley, 1010 Empire Building, Pittsburgh, Pennsylvania.

"WE RID OURSELVES OF NEEDLESS SHUTDOWNS—and DESTRUCTIVE HEATING IN SWITCHES by INSTALLING **BUSS** Super-Lag **FUSES**"

Says, Jacob Kovalchek, Chief Electrician for the makers of Gibbons Ale & Beer, Wilkes Barre, Pa.

Mr. Kovalchek explains . . "Heavy starting loads on our 150 h.p. motors were causing frequent blowing of the 400 ampere 600 volt fuses protecting the line. Another constant source of irritation was excessive heating in the switch which resulted in the spring tension being taken out of the clips and the fuse cases being destroyed by charring.

During May 1939, at the suggestion of a salesman, we installed 400 ampere BUSS Super-Lag Fuses. Since that time we have not had a single blow due to heavy starting and there has not been a sign of heating in either the fuses or the clips."

If you have shutdown complaints in Your Plant—just *"Pass the Buck"* to BUSS FUSES —they will Help You Out!

BUSS Super-Lag fuses have a time-lag feature that really does go a long way towards solving the shutdown problem—when the shutdowns are being caused by fuses blowing on temporary or momentary overcurrents.

. . . and needless blows caused by poor contact heating within the fuse itself have practically been eliminated in BUSS Super-Lag fuses by a Fuse-Case design worked out through years of laboratory and field tests.

That's why users of BUSS fuses enjoy a freedom from costly interruptions of electrical service that formerly were so often a burden upon the shoulders of the executives in charge of production or maintenance.

How to get action . . .

Just knowing about BUSS Super-Lag fuses doesn't save any money —unless the fuses are in your fuse clips. So why not get action that means money saving by passing the word along that from now on all fuses installed are to be BUSS Super-Lag fuses?

Your electrical wholesaler has or will get BUSS fuses for you.

Bussmann Manufacturing Co. • University and Jefferson • **St. Louis**

Division of McGraw Electric Company

BUSS Super-Lag FUSES

New ALLOY Plant for

▲ THE new plant of the Copperweld Steel Company, located on a 423 acre tract about two miles north of Warren, Ohio, offers a monthly capacity of about 12,000 tons of high grade electric furnace steel. The design of the plant is the result of the combined practical experience of the organization in the manufacture of alloy steels. Equipment was selected and laid out so as to give a smooth, efficient flow of material through the plant. Billets and bars, ½ in. to 8 in., may be rolled, and all grades of alloy and special steels are produced.

The melt shop, a building 78 ft. x 500 ft., houses two 25 ton and one 6 ton top-charged electric furnaces. With a diameter of 16 ft., the 25 ton furnaces are the largest top-charged electric melting furnaces in the United States, and are also equipped with the largest rated transformer capacity, 12,000 kva., which has so far been used on this size of furnace. The transformers have a range of ten secondary voltages, giving a high degree of flexibility from the rapid melting of light scrap to the reduced holding and refining voltages. Built into each transformer is a range of reactance values designed to give either the minimum impedance of the circuit, or equal increments of additional reactance as may be desired to suit the power system. Flexible cables, water-cooled and rubber-protected, carry the power to 18 in. graphite electrodes. Electrode travel is almost double that used in previous practice, a feature which reduces electrode slipping materially.

In order to effect the top charging, the furnace roof is of the swinging type, with a four-point suspension. A heavy oil-hydraulic lifting ram, combined with another oil-hydraulic cylinder for transverse motion, operates the roof movement, which requires only 30 seconds for each direction of travel. Paralleling, and adjacent to the melt shop is the stock house, 80 ft. x 33 ft. Scrap is handled by magnet from an overhead crane, and carefully sorted into six large scrap bins. An electric transfer car, carrying two cylindrical drop-bottom charging buckets, moves scrap to the furnaces. Limestone and dolomite are stored in elevated bins, and moved to the furnaces by crane. The various materials used as furnace or ladle additions are stored in bins along the charging floor. The charging operation may be completed in less than ten minutes. Due to the high electrical input to these furnaces, the melt-down is completed within a period of two hours. Refining is then carried out with the reduced inputs available.

After tapping, the ladles are carried to the pouring platforms, of which there are five, 75 ft. long, located at one end of the melt shop. Ladles are provided with two nozzles, so that two ingots may be poured simultaneously. Under-the-slag pouring is practiced, and the pouring speed and temperature are carefully watched. Moulds are of the corrugated type, 14 in. in diameter and 2100 lb. in weight. Very complete facilities are provided for maintaining and drying ladles, stopper rods, ingot moulds, and hot tops.

When complete solidification of the ingots is insured, they are stripped and conveyed either to the holding pits located near the stripper, or to the furnace building, about 150 ft. distant, over an ingot conveyor. Each of the six holding pits has a capacity for 36 ingots (one complete heat), and is fired with natural gas. They are used as a storage when heating capacity is unavailable at the blooming mill.

The furnace building is 100 ft. wide x 147 ft. long, and contains three in-and-out heating furnaces, with provisions for a fourth furnace should it be desired. The

The drop-bottom charging bucket at upper right carries scrap to the furnace, whose top has been lifted and swung to one side for top charging.

In tapping, the furnace is tilted by a balanced rocker type mechanism. Machined tracks and rocker faces, and high efficiency gearing materially reduce the tilting effort.

COPPERWELD *Steel Company*

furnaces are of double chamber design, with four doors placed along the one side wall. Ingots are placed against the furnace walls, in an upright position. Natural gas is fired through ten luminous burners located in the back wall, and directed toward the doors, the flame taking a U-shaped path along the roof and back along the furnace bottom to the flue system. Ingots are handled into and out of the heating furnaces by an overhead crane type charging machine.

Rolling facilities of the plant present a capacity of 20,000 tons per month, and include a blooming mill, a billet mill, and two bar mills. The bloomer is a 29 in. three-high unit driven by a 1500 hp. motor, and served front and rear by tilting tables and manipulators. From this mill, blooms pass through a crop shear and on to either a piling cradle or to the billet mill. The latter, located about 275 ft. beyond, and in line with, the blooming mill, is a 24 in. three-high stand, with tilting tables front and rear. Following this mill is an up-cut shear and a hot saw. With this set-up, material may be rolled direct, through the blooming and billet mills, with one heating, or, if necessary, the ingots may be broken down on the bloomer, removed at the piling cradle, conditioned, and returned to the primary heating furnaces for rolling on the 24 in. mill.

Beyond the 24 in. mill, material may be kicked into a cradle and transferred into holding pits by crane; or it may proceed on across a rail-type transfer bed for a longer period of cooling if desired.

The 29 in. and 24 in. mills are housed in a single building 71 ft. wide x 528 ft. long.

All surface conditioning is performed in a transept building, 80 ft. wide x 344 ft. long, which connects the blooming mill building to the bar mill building. Here are located chipping and grinding beds, two holding pits (in addition to two in the blooming mill building), and two 7 ft. x 22 ft. brick pickling tanks.

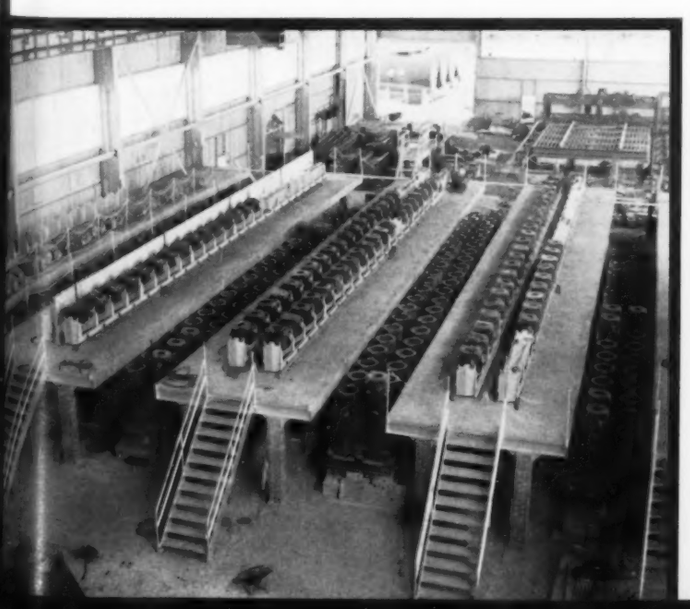
Further conversion into bars and rods is effected in the bar mills, which are located in a building 80 ft. wide x 925 ft. long and served by a single 21 ft. x 40 ft. continuous pusher-type heating furnace, fired with natural gas. The 18 in. bar mill consists of two three-high stands and one two-high stand placed side by side and driven by a single motor. The three pass lines are served by the necessary tables and cross transfers. After receiving the finishing pass in the two-high stand, the bars move on to a hot saw and cradle or hot bed. The first three-high stand of the 18 in. mill may also be used as a break-down stand for the 12 in. mill. The latter is a looping mill consisting of five two-high stands driven by a single motor. For still greater reductions, the material may then be passed through two 9 in. stands forming a parallel train at one side of the 12 in. mill.

From the 12 in. mill, bars are delivered to a double cooling bed 205 ft. long. Roller tables on each side of the cooling bed lead to shears and cradles. Material from the 9 in. stands is usually of rod size, and is delivered to either of two coiling reels.

At the finishing end of the bar mills, various processing equipment is installed, including a holding pit, two annealing furnaces, two straightening machines, and a gag press. There is also another building, 80 ft. x 580 ft., which will house additional finishing capacity.

A two story building, 40 ft. x 344 ft. is used for storeroom, machine shop, locker room, drafting room, and general offices. Another two story building, 39 ft. x 88 ft., provides space for chemical and metallurgical laboratories and offices.

Each of the four pouring aisles will accommodate two rows of 26 moulds each. Stools, on heavy I-beams supported by concrete piers, each hold six moulds.



Two ingots are poured simultaneously, with careful watch kept on teeming speed and temperature. The racks on the pouring platform are for hot top storage.

ONE *Good turn* AFTER ANOTHER

ON HYATT ROLLER BEARINGS tables, cranes, motors, and cars are increasing steel mill production, and profits. Everywhere it's just one good turn after another when shafts, gears, and wheels run on these dependable bearings. Specify Hyatts for your new equipment . . . use Hyatts for your changeovers. Where can we help *you?* Hyatt Bearings Division, General Motors Sales Corporation, Harrison, New Jersey; Chicago, Pittsburgh, Detroit and San Francisco.

This **UNITED 44" BLOOMING MILL**, with its Hyatt-equipped table, at Indiana Harbor, Youngstown Sheet & Tube, is typical of the many blooming and slabbing mills throughout the country, built by United, with Hyatt Roller Bearings.

HYATT

ROLLER BEARINGS

QUIET

FOLLANSBEE STEEL CORPORATION BEGINS MILLION DOLLAR MODERNIZATION PROGRAM

▲ Follansbee Steel Corporation announces that equipment has been ordered and construction work started on the $1,270,000 modernization program at the company's Follansbee, West Virginia, plant. New cold reducing mills and auxiliary equipment will be ready for operation by early Fall, and these will improve materially the company's competitive position on modern cold reduced products.

New equipment to be installed includes two 34 in. wide, single-stand, four-high reversing cold reducing mills and one 43 in., single-stand, four-high temper mill, along with auxiliary shearing, cleaning, pickling and annealing equipment. These mills, together with the present 38 in. wide cold reduction mill installed at the Follansbee plant in 1933, and such other of the company's present rolling equipment as will be continued in use, will give a total capacity of 145,200 tons per year of flat rolled products. These include sheets, tin plate, terne plate, roofing terne, black plate and electrical sheets.

Steel for electrical sheets, as heretofore, will be made in the Toronto, Ohio, plant, and the facilities for that production will be increased and improved. In making silicon steel for electrical sheets, the company will continue to use its open hearth furnaces, which are of the small stationary type particularly adapted to production of closely controlled and uniform heats. Similar close control of this product is maintained through the reheating furnaces, rolling mills, cold rolling and annealing operations. Follansbee is one of the few manufacturers of higher grade, low core loss silicon sheets.

The company's present operating equipment has been kept in excellent condition during the period of reorganization now concluded. Specially constructed tinning lines, including patented processing equipment for coating long terne sheets and seamless roll roofing, the latter a recent Follansbee development, are a feature of the tin house equipment.

NEW METAL STRENGTHENS PINION REDUCTION UNIT

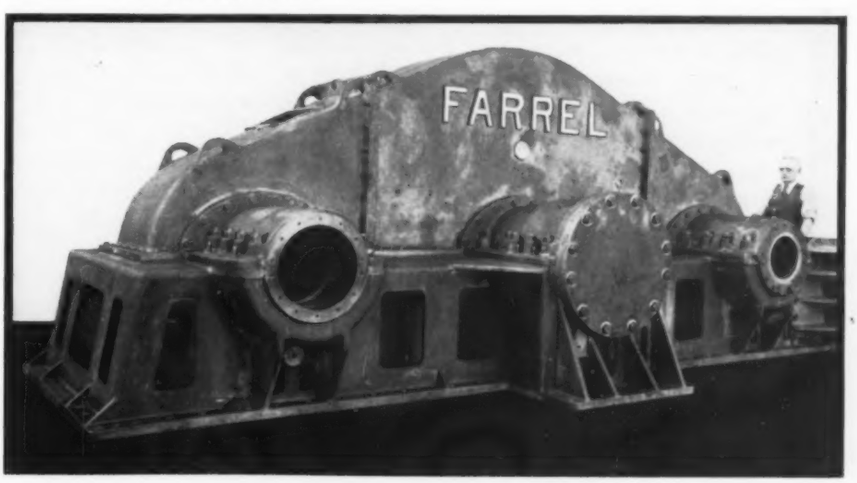
▲ For the five Maritime Commission C-1 ships, now building at the Western Pipe and Steel Company, San Francisco, the Farrel-Birmingham Company, Inc., is furnishing five two-pinion reduction units in which the housings, covers and bearing caps are made of Meehanite.

These castings were selected to be used in these gear drives for several reasons, First, it has been found that Meehanite has superior sound and vibration-dampening effect. Tests show that the material has a dampening effect seven times that of steel. Consequently the use of this material contributes to the smooth, quiet operation of the propulsion units.

Second, maximum stiffness and rigidity are assured by the use of this type of housing because the engineering design can be worked out to take advantage of the inherent characteristics of the metal and the method of its manufacture. Stiffness and rigidity are of great importance in keeping the pinions and gears in a two-pinion unit in strict alignment, which results in longer life for the revolving elements and less trouble with bearings and accessories.

After the casting is finished and cleaned of sand, it is placed in a stress-relieving oven and all casting stresses and strains are relieved. This assures that the casting will not change its

A casting material of process-inoculated iron containing a high percentage of heavy melting scrap and made in various processes to meet specific requirements was used in this gear case.



shape after being machined nor after it is installed in the vessel.

The housings of the propulsion gears for the five ships are cast from 35M Meehanite and have a minimum tensile strength of 40,000 lb. per square in. in the ladle test bars taken at the time of casting.

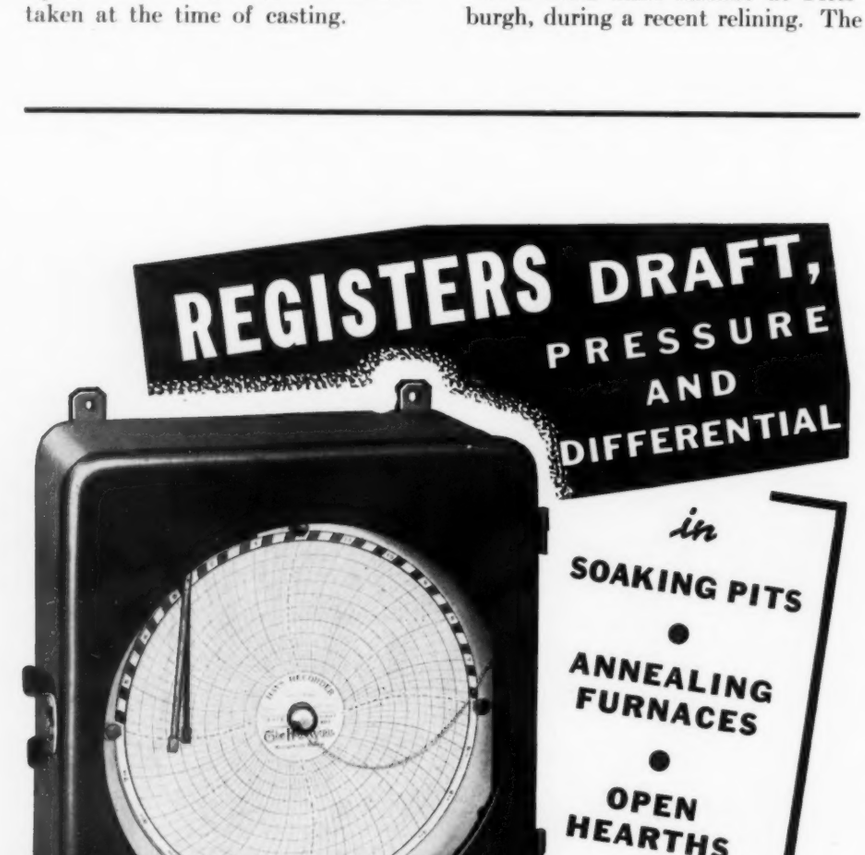
REPLACE LOWER SHELL ON STACK WITH EASE

▲ Jones and Laughlin Steel Corporation utilized an interesting replacement of the shell and mantle of their No. 5 Eliza blast furnace at Pittsburgh, during a recent relining. The shell and mantle replacement was made without disturbing the top structure, incline or downcomers. The upper shell and top structure had been replaced a number of years ago and were in good condition. The lower shell and mantle were considerably older and required replacement which was done by welding a new shell together outside the old for a height of 51 ft. This new shell was laid up against the old and riveted to it at the bottom and again at the upper level of the new shell.

Replacement of the shell and mantle was done by H. A. Brassert and Company. The method used was as follows: The bustle pipe was adequately supported by heavy timber posts. Then its hangers, as well as interfering butt plates and angles, were burned from the shell and removed. Then one section of the outside shell angle at the mantle, extending from one column to the next column was removed. The shell is supported by 12 columns equally spaced. A new plate section was fitted to the outside of the old bottom ring, the top edge being tight under the bottom edge of the second ring of old plates. A new section of heavy angle was fitted in at the mantle level and welded to the outside of the new plate.

This operation was repeated on the opposite side of the furnace. It was not considered advisable to replace the plates in continuous succession around the shell on account of the possibility of throwing the furnace out of plumb and level. Finally, the new bottom ring and its outside mantle angle were all fitted in place and securely welded together.

The top ring of the new shell was drawn in to fit against the lower ring of the plates which did not require renewal. The old shell was then burned out and the inside joints of all new plates welded. The old mantle was cut out, one section at a time, extending from the center of one column to the center of the next column, and 12 sections of mantle plate, with 12 splice plates over the columns were worked into place, until the whole ring was assembled and completely welded together. The old bottom or first shell ring with its inside angle was removed, a new inside angle was securely welded to the new mantle and shell plate, the drift pins at the top of the first ring were replaced with rivets, and 12 heavy brackets equally



HAYS "OT" DRAFT RECORDER

Results in a better product because it gives a correct indication of furnace atmospheres. Built husky enough to stand the severest steel mill conditions yet sensitive enough to register accurately in increments of .0025 in. water. Employs the famous Hays Slack Leather Diaphragm—self sealing—not damaged under sudden excess pressures. Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write to 955 Eighth Avenue, Michigan City, Indiana.

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

spaced between columns were welded to the inside of the shell and mantle.

DEVELOP DECARBONATOR FOR BOILER FEED WATER

▲ A decarbonator has been developed by the Cochrane Corporation primarily to meet the increasing demands of industrial and utility plants for trouble-free boiler feed water. While complete degasification usually is accomplished during the heating of the feed water, it may be desirable to remove such corrosive gases as carbon dioxide and hydrogen sulphide from the water in a cold condition without regard to other soluble gases such as oxygen.

The decarbonator is currently used to remove carbon dioxide from the effluent of carbonaceous hydrogen zeolite softeners and from water supplies treated with acid. Where soluble iron and carbon dioxide are present in the natural water supply, as they are in many parts of the country, the decarbonator removes the dissolved carbon dioxide and by aeration oxidizes the soluble iron so that it may be filtered out and the water made fit for use.

ARMCO ENLARGES STACK TO INCREASE CAPACITY

▲ American Rolling Mill Company announced that the No. 2 blast furnace at its Hamilton, Ohio, plant would be enlarged. The capacity of the furnace will be increased from 350 tons of pig iron per day to 650 tons and the remodeling will cost an estimated $400,000. Construction work will begin about August 15. Three months will be required to get the furnace back into operation. The construction work, as well as the designing of the furnace, will be done by Arthur G. McKee and Company. The enlargement of the furnace will not mean any increase in the permanent force, Armco men already on the payrolls will be employed on the construction job.

The present furnace was moved to Hamilton from the company's Columbus, Ohio, plant a few years ago. Its enlargement is made necessary by an increased need for hot pig iron for the open hearths at Middletown Works, and a growing demand for merchant pig iron from foundries in the middlewest. The molten pig iron is tapped from the blast furnaces into huge ladle cars, built like thermos bottles. When loaded, each car weighs 350 tons. They are transported to the open hearths in Middletown, a distance of eleven miles, over a specially built railroad of heavy construction to carry this tremendous weight.

STAINLESS STEEL PLANT DOUBLES WIRE CAPACITY

▲ Allegheny-Ludlum Steel Corporation has made great strides in the construction of a building to house the stainless steel wire mill at the Dunkirk, New York, plant. This is the fourth time stainless steel wire

10 ton-100'-0" span Cleveland all-welded crane with sheet lifter in a modern steel mill

THE BIG MILLS CHOOSE

CLEVELAND *all-welded* CRANES

Because so much depends on the crane service in the big mills, more and more Cleveland all-welded cranes are being purchased by them.

Cleveland all-weldeds are cheap insurance that *uninterrupted* crane service will be had whenever needed.

You, too, might prevent costly delays by installing Cleveland all-welded cranes.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES

ALL-WELDED OVERHEAD TRAVELING CRANES

Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

capacity has been doubled, and the third that additional buildings have been erected to provide for rapidly increasing demands. The building will house the very latest designed equipment which will have greatly increased drawing speeds.

The plant will be the only one of its kind in this country devoted in its entirety to production of stainless steel wire from the hot rod down to .003 in. gauge. When the new stainless wire mill addition is completed, more men will be employed, resulting in an increased payroll of at least 50 per cent.

When repair work must stand up

Here's another important repair job. This 300 HP. 3 phase motor drives a wire drawing machine at a prominent copper company. It was completely rewound by Premier Electric & Engineering Company of New York City. This prominent electrical engineering concern has standardized on DOLPH'S CHINALAK Black Baking Varnish for a number of years.

In the steel industry too, CHINALAK has earned an enviable record. Many steel mills have standardized on this grade for maintenance purposes. Others specify its use on windings when purchasing new motorized equipment.

Are your electrical engineers fully aware of all the outstanding qualities of this unusual insulating varnish? If not, why not suggest that they communicate with us? We will gladly send the full story without obligation.

JOHN C. DOLPH CO.

Insulating Varnish Specialists

166A Emmett Street NEWARK, N. J.

NEW LITERATURE

▲ Homestead Valve Manufacturing Company, Inc., has published two new folders. One is a folder on the subject of valves, which gives examples of the extremely low upkeep of Homestead valves. Tables showing specific technical data are also included with illustrations of typical examples.

The second booklet describes "Hypressure Jenny," the original steam cleaner. The many varied uses of this cleaner are described with the savings obtained by cleaning with this cleaner. These booklets may be obtained by writing to the Homestead Valve Manufacturing Company, Inc., Coraopolis, Pennsylvania.

▲ Allis-Chalmers Manufacturing Company has issued a new bulletin designed for inclusion in your catalogue book. The book is entitled "Synchronous Motors—Coupled and Engine Types." A feature of this complete catalogue, is the detailed description of the construction of Allis-Chalmers' synchronous motors. Technically described are the following: (1) stator construction; (2) rotor construction; (3) bearings and shafts —ring oiling bearings; (4) exciters. Starting of synchronous motors is also thoroughly covered, including: reduced voltage starting; primary switching; field application; and types of starters.

Write to Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, requesting Bulletin No. B-6033.

▲ Trumbull Electric Manufacturing Company is distributing throughout the trade a new circular illustrating and explaining in detail the many exclusive features of its entire line of across-the-line magnetic starters. This circular, suitable for loose-leaf files, may be obtained by writing to the Trumbull Electric Manufacturing Company, Plainville, Connecticut, and requesting Bulletin No. 322.

▲ Link-Belt Company has published a new 20-page illustrated catalogue on "Link-Belt Vibrating Screens." These screens effectively screen a great variety of materials such as sand, gravel, cinders, grain, clay, crushed stone, coke, coal, ore, etc. A copy of this book may be obtained by writing the Link-Belt Company, 307 North Michigan Avenue, Chicago, Illinois. Please request Bulletin No. 1762.

ITEMS OF INTEREST

C. Clarke Wales was recently elected vice-president and a director of the Hamilton Bridge Company, Hamilton, Ontario, Canada. Mr. Wales, until this appointment, has been general manager of this company.

Mr. Wales was graduated from the University of Toronto, with a degree of B.A., S.C. in mechanical engineering. He entered the employ of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania, following his graduation. In 1925 he joined the Otis Steel Company, later becoming assistant metallurgist and then superintendent of the open hearth, 40 in. blooming mill and bar mills. He later served as chief engineer of this company, during which period he directed and planned the construction of the 72 in. hot and cold strip mills. In 1937 he was appointed assistant general manager of the Algoma Steel Corporation, Ltd., of Sault Ste. Marie, Ontario, Canada. In 1939 he went to the Hamilton Bridge Company as general manager.

An active member of the Association of Iron and Steel Engineers, Mr. Wales is also a member of the Board of Directors of the Association as a past-president.

Max W. Lightner has been appointed assistant to general superintendent at the Homestead Works of the Carnegie-Illinois Steel Corporation. He was formerly chief metallurgist at Homestead. Mr. Lightner, who received degrees in metallurgy from the Pennsylvania State College and Carnegie Institute of Technology, began his corporation service as an assistant metallurgist at Homestead in 1933. He was appointed assistant chief metallurgist November 16, 1934, and became assistant superintendent of open hearth No. 4 on September 1, 1936. He has been chief metallurgist since March 1, 1937.

S. W. Gibb was promoted to the position of general sales manager of the Philadelphia division of the Yale and Towne Manufacturing Company. Mr. Gibb comes to his new job backed by experience gained through 20 years of executive work with the Yale organization. Joining the company in 1920, as district sales manager, he operated from Pittsburgh headquarters for the next several years. In 1929, he was promoted to Pacific Coast sales manager, and in 1931 he was made assistant sales manager for the entire materials handling division in Philadelphia, Pennsylvania.

Warren W. Scherer, formerly superintendent of maintenance, Carnegie-Illinois Steel Corporation, Irvin Works, Dravosburg, Pennsylvania, has been named superintendent of industrial relations at that plant. **Arthur M. Krieger** has been made superintendent of maintenance at the Irvin Works. Other employees promoted and their new titles are: **John A. Drgon,** assistant superintendent of maintenance; **Thomas W. Hunter,** assistant division superintendent, flat products finishing; **Charles A. Larkin,** general foreman, cold reductions; **William Springfield,** lubrication foreman, maintenance, and **John Sturdy,** maintenance foreman, flat products finishing.

M. M. Cadman will succeed MacGilvray Shiras as director of raw materials for Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. Mr. Cadman attended high school in Pittsburgh and was graduated from the Pennsylvania State College in mining and metallurgy in 1898. On June 1, 1903, he joined the Carnegie Steel Company as assistant ore agent. He was appointed assistant director of raw materials in October, 1935.

J. H. Slater, formerly superintendent of blast furnaces and coke works of the Republic Steel Corporation's Cleveland district, has been appointed assistant manager in charge of steel works. Mr. Slater was born in Detroit and received his grade and high school education in Cleveland. He graduated from Case School of Applied Science in 1912 as a mining and metallurgical engineer, going directly to the Central Furnaces of American Steel and Wire Company as stove tender. From that company he joined the National Tube Company in Lorain, Ohio, as a blower and remained there until 1916, when he went with the United Furnace

MAX W. LIGHTNER

S. W. GIBB

ARTHUR M. KRIEGER

Company at Canton, as general foreman of the blast furnace department.

In 1920 he was promoted to blast furnace superintendent and in 1932 was transferred to Warren, where he was made superintendent of blast furnaces and coke ovens at the Trumbull-Cliffs furnace. He went to Cleveland in 1935 to take charge of the blast furnaces and coke ovens.

Republic Steel Corporation has announced the following changes in personnel:

H. H. Holloway, assistant district manager, Cleveland, Ohio, has been placed in charge of all finishing mills.

B. W. Norton, formerly assistant district manager at Youngstown, Ohio, has been transferred to the same position in the Warren district. Mr. Norton, who had been superintendent of blast furnaces and coke plant at Youngstown, was appointed assistant manager in 1937.

J. H. Graft, assistant district manager at Warren, is transferred to Youngstown as assistant district manager. Before his appointment as assistant district manager in 1939, Mr. Graft was superintendent of the electrical department, in Youngstown.

M. D. Wald, formerly superintendent of the coke ovens in the Cleveland district, succeeds Mr. Slater as superintendent of the blast furnaces, coke ovens and docks.

C. M. Schoenlaub, assistant superintendent of the Warren open hearth department, has been made assistant superintendent of the Cleveland open hearth department.

B. D. McCarthey, assistant superintendent of the Cleveland open hearth department, has been transferred to Warren in the same capacity.

William Rodgers, formerly chief metallurgist at Buffalo, has been appointed chief metallurgist of the Cleveland district.

P. P. Echols, formerly chief metallurgist at Warren, was made assistant chief metallurgist of the Cleveland district.

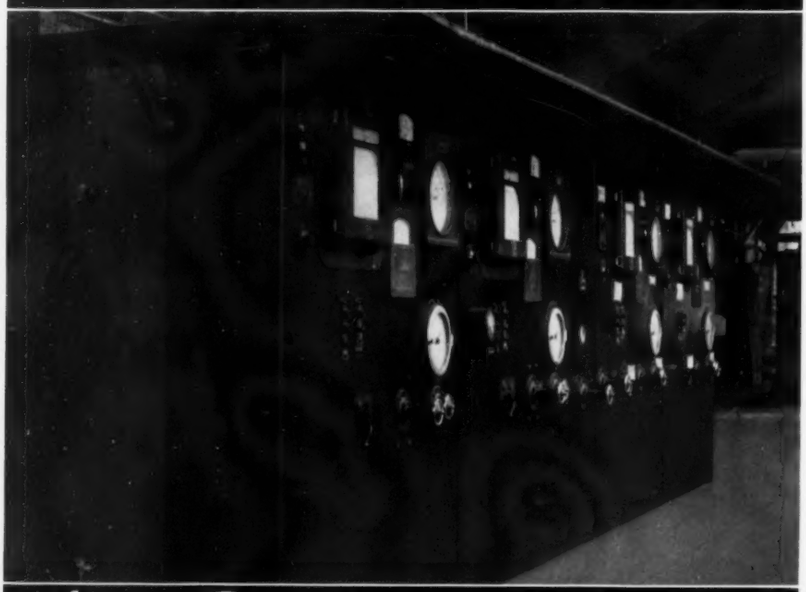
J. J. Bowden, formerly chief metallurgist of the Cleveland district, is now chief metallurgist of the Warren district.

J. D. Dickerson, formerly assistant chief metallurgist at Buffalo, has been named chief metallurgist.

Charles P. Kimmel, assistant to the general superintendent, Carnegie-Illinois Steel Corporation, Gary Works, retired last week after 51 years of service to the steel industry. Mr. Kimmel became associated with this industry at the age of 16 years, when he became a machine shop apprentice in the Pueblo, Colorado, plant of the Colorado Coal and Iron Company. After seven years he had worked himself up to roll turner and went to Paterson, New Jersey, to work for the Passaic Rolling Mill Company. Two years later he was back at Pueblo as a journeyman roll turner and then templet filer. In 1908 he went to Gary as roll shop superintendent of the then unfinished Gary

(*Please turn to page 78*)

PRECISION CONTROL



-for a Precision Industry

THERE is precision . . . and there is ASKANIA precision. Steel men recognize this important difference. They have learned how vitally important this higher degree of precision is to an industry that constantly seeks for product improvement and lower operating costs.

A typical example of ASKANIA precision is found in the control equipment for furnace pressure, combustion and automatic correction for changes in gas density applied to a four hole soaking pit, the control panel of which is illustrated above. The accurate Askania control maintains correct furnace atmosphere and pressure which cuts fuel costs . . . reduces scale loss . . . eliminates washing . . . lowers chipping costs. Furthermore, it aids efficient operation by quickly following the opening and closing of the pit cover.

▶Get the benefits of the rugged, accurate and positive operation of Askania Control for soaking pits or any other application in the mill.

ASKANIA REGULATOR CO.
1603 S. Michigan Ave., Chicago, Ill.

ASKANIA CHICAGO

Automatic CONTROL

"IF IT CAN BE MEASURED—WE CAN CONTROL IT"

"HEAT-CONDITION" YOUR PLANT *with* ROCKBESTOS *heat-resisting wires*

Here's real help for you in condensed form. Clip out and keep this page for quick reference when you reach the wire-specifying stage of your planning. If any of the wiring in your plant is exposed to heat, oil, grease, corrosive fumes or fire hazard—then you need Rockbestos. We show but a few of our wide line of asbestos insulated wires and cables. Samples and our red-covered No. 10-E Catalog on request. Read the descriptions and learn how our wires may help you.

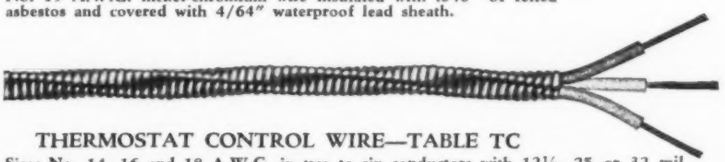
Rockbestos Products Corporation, 960 Nicoll Street, New Haven, Connecticut

INDUSTRIAL HEATING CABLE—TABLE LH

No. 19 A.W.G. nickel-chromium wire insulated with .040" of felted asbestos and covered with 4/64" waterproof lead sheath.

This pliable cable distributes a mild heat evenly over large areas. Prevents freezing of water pipes, wet pipe sprinkler systems, etc. Keeps conveyor pipes for soap, varnish, ink, chocolate, etc., at temperatures that insure even flow. Send for folder.

★



THERMOSTAT CONTROL WIRE—TABLE TC

Sizes No. 14, 16 and 18 A.W.G. in two to six conductors with 12½, 25 or 32 mil wall of felted asbestos insulation and cadmium plated steel armor.

A multi-conductor control wire for low voltage intercommunicating, signal and temperature control systems. Its lifetime insulation and metal braid armor will give you troubleproof circuits.

★

600 VOLT A.V.C. BOILER ROOM WIRE—TABLE C

Sizes No. 18 to No. 0000 A.W.G. This construction for sizes 18 to 8, sizes 6 to 0000 have another felted wall next to the conductor.

For lighting and control circuits exposed to heat and moisture, oil, grease, fumes or fire hazard, such as exist around furnaces, ovens, lehrs, soaking pits, boilers, etc., this widely-used A.V.C. construction is ideal. Also for locomotive panel wiring and for switchboards on which an asbestos braided wire is required.

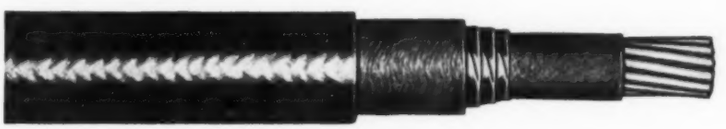
★

600 VOLT ALL-ASBESTOS RHEOSTAT CABLE—TABLE R

Sizes No. 18 A.W.G. to 2,500,000 CM insulated with a heavy wall of felted asbestos and a rugged asbestos braid. Finished in black, white or colors.

Use this power and rheostat cable or Table A, All-Asbestos Rheostat Wire for wiring rheostats, switchboards, elevator and locomotive control panels and electrical equipment exposed to heat, fumes or fire hazard. Also for general open wiring in hot locations.

★

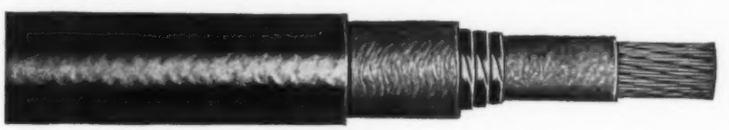


600 VOLT A.V.C. POWER CABLE—TABLE E

Sizes No. 18 A.W.G. to 2,500,000 CM insulated with laminated felted asbestos and varnished cambric, and asbestos braid. Other constructions for service voltages up to 8000.

This cable is recommended for power circuits and hot-spot wiring in or around boiler rooms, ash pits, steam tunnels, soaking pits, tenter frames, glass plants, steel mills, etc. The asbestos and heat-sealed varnished cambric construction has ample moisture resistance and withstands high temperatures indefinitely without failure.

★

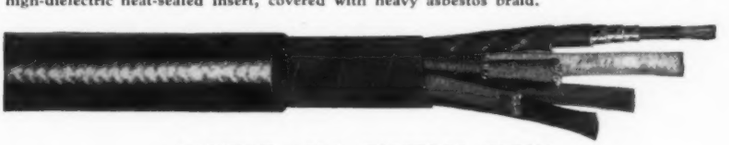


600 VOLT A.V.C. MOTOR LEAD AND APPARATUS CABLE—TABLE L

Sizes No. 18 A.W.G. to 1,000,000 CM insulated with two walls of felted asbestos and a high-dielectric heat-sealed insert, covered with heavy asbestos braid.

Heatproof, fireproof, greaseproof and oilproof, this cable will not dry out and crack, won't burn or carry flame, and will remain permanently flexible. For coil connections, motor and transformer leads where extreme heat and fire hazards are encountered as in steel mills, boiler rooms, etc.

★



600 VOLT A.V.C. CONTROL CABLE

In one to 19 conductors. Standard stranding A.W.G. No. 12—19/25 and No. 9—19/22. Other strandings furnished to order.

Designed for use under conditions too severe for control cables with other types of insulation which deteriorate rapidly when exposed to high temperatures. Operates without failure under the attack of heat, oil, grease or corrosive fumes and is suitable for installation either open or in conduit as it has ample moisture resistance.

★

Also refer to Electrical Contracting and Electrical World Buyer's Reference Editions.

ROCKBESTOS—*the wire with permanent insulation*

(*Continued from page 76*)

Works. In 1914 he was named merchant mill superintendent and assistant works superintendent four years later. When Walter Hadley replaced W. P. Gleason as general superintendent in 1936, this title was changed to assistant general superintendent. In 1937 this title was passed on to Stephen Jenks and Mr. Kimmel became known as assistant to the general superintendent.

David L. Mekeel has retired from active duty with the Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania, to enter the steel mill consultant field. He will be located in Pittsburgh with temporary offices at his residence in Coraopolis Heights, Pennsylvania.

Irvin S. Olds succeeded Edward R. Stettinius, Jr., as chairman of the board of directors and as a member of the finance committee of the United States Steel Corporation. Mr. Olds was born in Erie, Pennsylvania, in 1887. He is a graduate of Yale and Harvard Law School and was admitted to the bar in Pennsylvania in 1910 and in New York in 1912. He was secretary to Justice Holmes of the United States Supreme Court, 1910 and 1911, becoming connected with White and Case, a New York legal firm, in August, 1911, and admitted as a partner in January, 1917. During 1917–1919, Mr. Olds served as counsel for the purchasing department of the British war mission to the United States and in 1918 was a special assistant in the United States war department. Since 1918 he has been a member of the firm of White and Case, engaged in legal work related to matters of organization and administration of corporate business enterprises. He has been a director and member of the finance committee of the United States Steel Corporation since October 27, 1936.

O. P. Robinson has been appointed to the sales engineering staff of Cutler-Hammer, Inc., in their Pittsburgh office. Mr. Robinson was with the company's Chicago office prior to this present appointment. He is an electrical engineer graduate of the Armour Institute of Technology.

Chester H. Lang, manager of General Electric Company's advertising and sales promotion activities since 1932, has been named manager of apparatus sales and vice-chairman of the company's apparatus sales committee. Mr. Lang, a native of Erie, Pennsylvania, and a graduate of the University of Michigan, entered the employ of General Electric as a traveling auditor, in 1919. In 1922 he was made assistant manager of the publicity department. He continued in this position until 1926 when he was named comptroller of the budget, a position he held until 1932 when he became advertising manager.

Type DE Safety Flange Couplings on Steel Mill Drive

FARREL GEARFLEX* COUPLINGS

are Easy to Install . . . Easy to Align . . . Easy to Disassemble . . . Easy to Maintain

Sectional View of Type DE Gearflex Coupling

•

Send for new catalog No. 443 giving complete descriptive and engineering data on all types of Farrel Flexible Couplings.

The simplicity of Farrel Gearflex* Couplings adds to their outstanding mechanical merit. Simple to install; easy to align, with straight edge and feeler. They are disconnected with ordinary tools and without endwise movement of either shaft. They require no maintenance, only periodic lubrication with a standard grade of oil available everywhere. Gearflex Couplings meet any criterion for a flexible coupling in function and application.

*Trade Mark Reg. U. S. Patent Office.

FARREL-BIRMINGHAM COMPANY, INC.
366 VULCAN STREET BUFFALO, N. Y.

FARREL SYKES GEARS — *The Gear with a Backbone*